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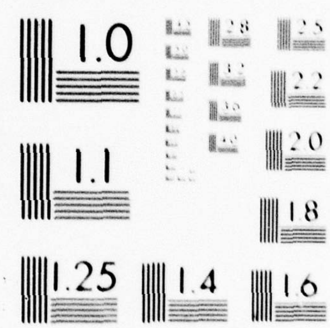

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TR 18-78

DEFENSE COMMUNICATIONS ENGINEERING CENTER

TECHINICAL REPORT NO. 18-78

DESIGN CONCEPTS FOR THE NEXT GENERATION CONUS AUTOVON

DECEMBER 1978

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7. AUTHOR(s) R.F. Deardorff, W.P. Dotson, T.C. Harris, W.G. Hartung, J.E. Knepley, N.A. Sica, T.M. Shimabukuro, E.M. Stubsten, G.W. Swinsky, W.F. Vogelzang		8. CONTRACT OR GRANT NUMBER(s)
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AUTOVON II	Digital Transmission	TELPAK
Common Channel Signaling (CCS)	Tariffs	SCAN
Alternatives	Operational Network	WATS

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report reviews technological developments in commercial telecommunications in switching, terrestrial transmission and satellite communications. Based on this assessment, six alternatives were postulated, and analyzed to gain a better understanding of the fundamental structure, relationships and sensitivities of cost, survivability and performance considerations. The study indicates that there is a potential for large savings by exploiting the technological improvements in commercial communications. Although the uncertainties are very large for the more radical alternatives, the major risks are not technical. (OVER)

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20. Continued

No single alternative is the preferred alternative. A composite of the best attributes of each is recommended.and an implementation strategy is postulated.

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DESIGN CONCEPTS FOR THE

NEXT GENERATION CONUS AUTOVON

DECEMBER 1978

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FOREWORD

The Defense Communications Engineering Center Technical Reports (TR's) are published to inform interested members of the defense community regarding technical activities of the Center, completed and in progress. They are intended to stimulate thinking, encourage information exchange, and provide guidance for related planning and research. They are not an integral part of the DoD PPBS cycle and should not be interpreted as a source of program guidance.

Comments or technical inquiries concerning this document are welcome, and should be directed to:

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TABLE OF CONTENTS

		Page
	EXECUTIVE SUMMARY	ES-1
I.	INTRODUCTION	I-1
	1. Purpose	I-1
	2. Scope	I-1
	3. Organization of The Report	I-2
	4. Relationship to Other Documents	I-3
II.	BACKGROUND	II-1
	1. History of CONUS AUTOVON	II-1
	2. Changes to Tariffing Arrangements	II-2
	3. The Changing Technology	II-5
	4. The Director's Request For The Study	II-5
III.	IMPLICATIONS OF TECHNOLOGICAL DEVELOPMENT	III-1
	1. Commercial Telecommunications	III-1
	2. DCS III Concepts	III-16
IV.	NEXT GENERATION CONUS AUTOVON ALTERNATIVES	IV-1
	1. Introduction	IV-1
	2. CONUS AUTOVON Requirements	IV-1
	3. System Design Goals and Performance Objectives	IV-6
	4. Approaches to Planning and Engineering The CONUS AUTOVON	IV-8
	5. Description of Alternatives Under Study	IV-9
	6. Assumptions and Constraints	IV-21
V.	ANALYSIS RESULTS AND PREFERRED SYSTEM ATTRIBUTES	V-1
	1. Introduction	V-1
	2. Results Relevant to The Three Basic Approaches	V-1
	3. Cost and Survivability Results For The Alternatives	V-9
	4. Preferred System Attributes	V-26

TABLE OF CONTENTS (Continued)

		Page
VI.	PLANNING AND IMPLEMENTATION STRATEGY	VI-1
	1. Introduction	VI-1
	2. Major Events Affecting The Next Generation CONUS AUTOVON	VI-1
	3. Decision-Making For Implementation	VI-4
	4. The Implementation Environment	VI-14
VII.	SIGNIFICANT FINDINGS AND CONCLUSIONS	VII-1
	1. Significant Findings	VII-1
	2. Recommendations	VII-3
	REFERENCES	1
	GLOSSARY OF TERMS	2
APPENDIXES		
A.	AUTOVON II Requirements	A-1
B.	Common Channel Signaling and AUTOVON Routing Philosophy	B-1
C.	Network Design and Economic Analysis	C-1
D.	Survivability	D-1
E.	Network Management Implications	E-1
F.	Attributes of the Next Generation CONUS AUTOVON	F-1
G.	Policies	G-1

LIST OF ILLUSTRATIONS

Figure	Title	Page
1	CONUS AUTOVON ANNUAL COSTS	ES-2
2.	COST VS. NUMBER OF SWITCHES	ES-7
3.	SURVIVABILITY MEASURE AS A FUNCTION OF THE NUMBER OF SWITCHES	ES-8
4.	NETWORK SURVIVABILITY COMPARISON OF BASIC APPROACHES	ES-10
5.	MAJOR EVENTS RELEVANT TO THE NEXT GENERATION CONUS AUTOVON IN THE TIME FRAME UP TO 1992	ES-15
6.	STRATEGIES FOR IMPLEMENTATION FOR THE NEXT GENERATION CONUS AUTOVON	ES-16
II-1.	SCAN SWITCH UTILIZATION	II-3
II-2.	CONUS AUTOVON ANNUAL COSTS	II-6
III-1.	AT&T LONG LINES INVESTMENT PER CIRCUIT MILE	III-2
III-2.	THE CHANGING TECHNOLOGY IN AT&T's LONG LINES TRANSMISSION CARRIER FACILITIES	III-4
III-3.	INCREASING CAPACITY ON AT&T's LONG LINES TD-2 MICROWAVE SYSTEM	III-5
III-4.	COMMPARISON OF CAPABILITIES NO. 4A CROSSBAR VS. NO. 4ESS	III-7
IV-1.	ALTERNATIVE 2	IV-12
IV-2.	ALTERNATIVE 3	IV-15
IV-3.	ALTERNATIVE 4	IV-16
IV-4.	ALTERNATIVE 5	IV-18
IV-5.	ALTERNATIVE 6	IV-20

LIST OF ILLUSTRATIONS (CONT'D)

Figure	Title	Page
V-1.	COST VS NUMBER OF SWITCHES	V-3
V-2.	SURVIVABILITY MEASURE AS A FUNCTION OF THE NUMBER OF SWITCHES	V-4
V-3.	NETWORK SURVIVABILITY COMPARISON OF BASIC APPROACHES	V-8
V-4.	COST VS SATELLITE UTILIZATION	V-13
V-5.	AVERAGE HOURLY TRAFFIC LOAD	V-15
V-6.	TRAFFIC PROFILE OVER SEVERAL DAYS	V-16
V-7.	NETWORK SURVIVABILITY COMPARISON OF ALTERNATIVES	V-18
V-8.	COST COMPARISONS OF ALTERNATIVES	V-19
V-9.	SENSITIVITY OF ALTERNATIVES TO ASSOCIATED CCS AND MLPP	V-22
VI-1.	MAJOR EVENTS RELEVANT TO THE NEXT GENERATION CONUS AUTOVON IN THE TIME FRAME UP TO 1992	VI-3
VI-2.	STRATEGIES FOR IMPLEMENTATION OF THE NEXT GENERATION CONUS AUTOVON	VI-5
VI-3.	CONUS AUTOVON IN 1978	VI-8
VI-4.	CONUS AUTOVON IN 1982	VI-10
VI-5.	CONUS AUTOVON IN 1987	VI-12
VI-6.	CONUS AUTOVON IN 1992	VI-13

LIST OF TABLES

Table	Title	Page
I.	DEFINITION OF CONUS AUTOVON ALTERNATIVES	ES-5
II.	TEN-YEAR LIFE CYCLE COSTS	ES-6
III.	SUMMARY OF RESULTS	ES-11
IV.	NON-QUANTIFIABLE UNCERTAINTIES	ES-12
V.	PREFERRED ATTRIBUTES BASED ON COST AND SUBJECTIVE ANALYSIS	ES-13
III-I.	SUMMARY OF BENEFITS OF THE BASCOP ARCHITECTURE	III-11
IV-I.	SYSTEM PERFORMANCE AND CAPABILITIES OBJECTIVES FOR CONUS AUTOVON	IV-3
IV-II.	DEFINITION OF CONUS AUTOVON ALTERNATIVES	IV-10
V-I.	TEN-YEAR LIFE CYCLE COSTS	V-6
V-II.	SUMMARY OF RESULTS	V-10
V-III.	QUANTIFIABLE UNCERTAINTIES	V-20
V-IV.	NON-QUANTIFIABLE UNCERTAINTIES	V-24
V-V.	PREFERRED ATTRIBUTES BASED ON COST AND SUBJECTIVE ANALYSIS	V-27

EXECUTIVE SUMMARY

I. INTRODUCTION

This Technical Report documents the results of studies, seminars, and analyses concerning the cost, survivability, and other factors that drive the evolutionary strategy for the Next Generation CONUS AUTOVON (AUTOVON II). This work, in accordance with a request from the Director, DCA, is to result in consideration of alternatives for AUTOVON II as part of DCA's ten year planning efforts.

The scope of this effort is limited to considerations for AUTOVON within the contiguous 48 states for purposes of identifying preferred AUTOVON attributes based upon technological and economic opportunities in a changing U.S. regulatory environment.

II. BACKGROUND

1. The Rising Costs of AUTOVON

The DoD is charged for AUTOVON services under several tariff arrangements. The bulk of these charges in CONUS are known as the Switched Circuit Automatic Network (SCAN) arrangement for switching centers and the TELPAK arrangement for interswitch trunks and access lines. The Canadian Switched Network (CSN) and some small portions of the CONUS network utilize other tariff arrangements. The total annual charges for the CONUS/CSN AUTOVON amounted to almost $100 million in 1977.

Revisions to the AT&T tariff FCC No. 260, including the changes to the SCAN arrangement and the probable demise of TELPAK, are expected to result in an increase in CONUS charges of $46 million a year in current dollars. This is graphically depicted in Figure 1. The Canadian costs are not affected.

The DCA has decided to close six of the CONUS switches. However, the demise of TELPAK and the effects of inflation will raise annual costs of the present network to a value between $154 and 219 million per year by 1985.

2. Tasking by Director, DCA

As a result of the realities noted above, the Director, DCA, requested, during a review of the DCA ten year planning efforts, that more economical CONUS AUTOVON service alternatives be explored, including a future AUTOVON which may be characterized by "traveling classmarks" in the Bell System's network of No. 4 ESS machines, or which may exploit satellite carrier services.

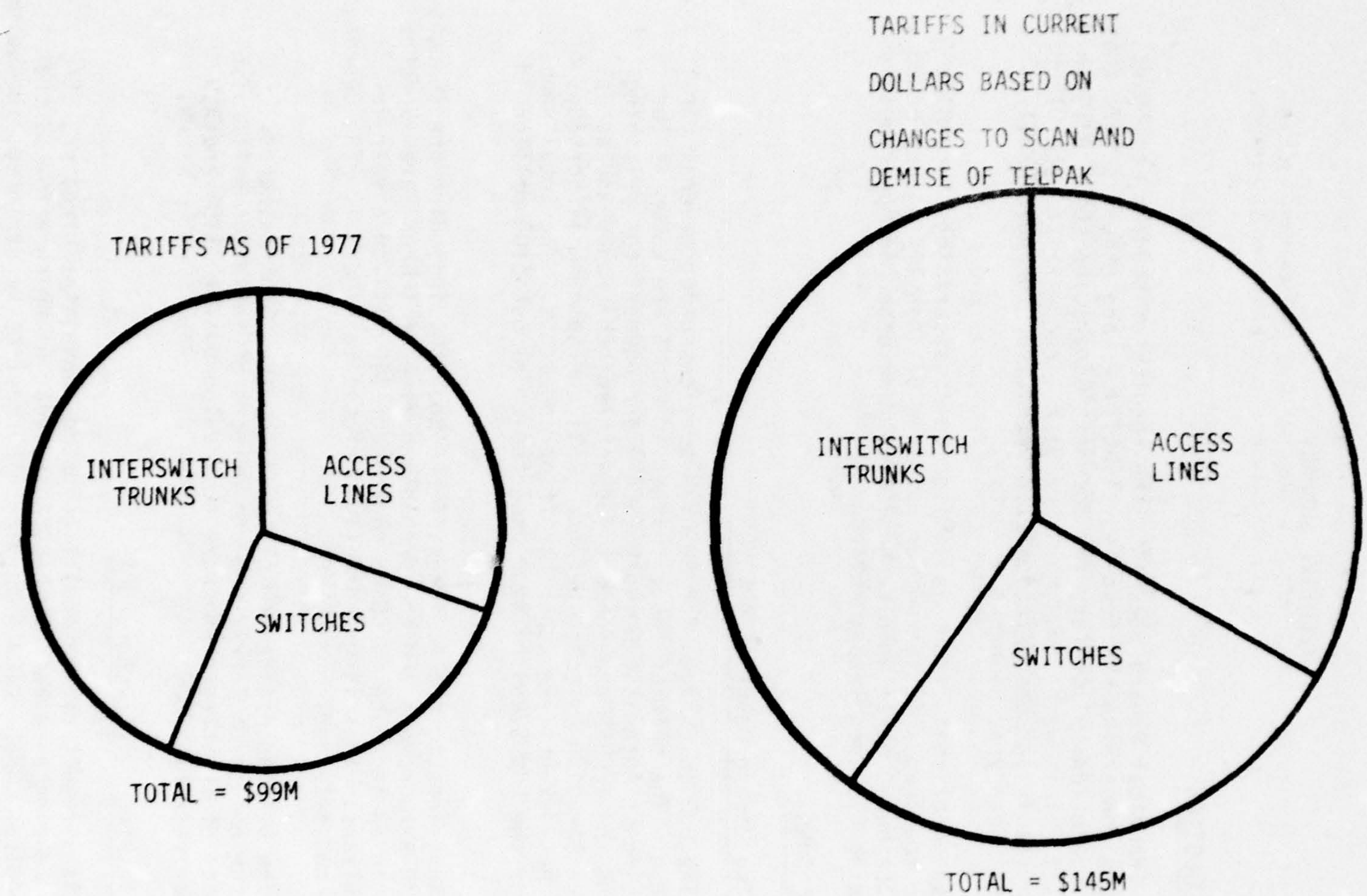


Figure 1. CONUS/CSN Annual Costs

III. IMPLICATIONS OF TECHNOLOGICAL DEVELOPMENT

This Technical Report first reviews commercial telecommunications in switching, terrestrial transmission, and satellite communications (see section III of the main report).

The results of seminars and studies conducted at DCEC indicate that the following technological developments in commercial telecommunications have potential for minimizing future CONUS AUTOVON costs, and for increasing features and capabilities for the FY 82-92 time frame:

- Rapid implementation of the digital No. 4 ESS machines within the United States by the Bell System and Independent Telephone Companies as part of a gradual evolution from the Switched Analog Network (SAN) to the Switched Digital Network (SDN). It is anticipated that 87 No. 4 ESS switches will be operating by 1982 with 12 to 15 per year being added annually thereafter.

- A growing availability of economical commercial digital private branch exchanges (PBX), and Class 4/5 offices with remote switching units, compatible with commercial T1 digital lines, which makes it possible to place network "intelligence" (e.g., routing and control) at levels closer to the user instead of embedding it in the backbone structure.

- Availability in the early 1980's of small commercial satellite terminals which may be located close to user premises, offering the potential to reduce access line and interswitch trunk charges.

IV. NEXT GENERATION CONUS AUTOVON ALTERNATIVES

For the purposes of this study, it was convenient to examine a limited number of sufficiently different approaches to determine the advantages and disadvantages of each concept.

Based on the assessment of section III, six alternatives were postulated, reviewed by the appropriate directorates and divisions of the DCA and DCEC, and approved for more detailed addressal by the Director, DCA (section IV).

The six alternatives were grouped into the following concepts or design approaches:

- Continue the present concept; lease a dedicated AUTOVON from AT&T and the Independent Telephone Companies.

- Follow the telephone industry service offerings and take advantage of their plans and developments as introduced to the public at large.

- Create a new CONUS AUTOVON based on new technology.

The design approaches and the six alternatives are summarized in Table I and explained in detail in section IV.

V. COST IMPLICATIONS AND PREFERRED SYSTEM ATTRIBUTES

The six alternatives were analyzed by DCEC to gain a better understanding of the fundamental structure, relationships, and sensitivities of cost, survivability, and performance considerations (section V).

1. Results Relevant to the Three Basic Approaches

Ten-year life cycle costs estimated for the three design approaches are summarized in Table II.

The potential for savings in the first design approach is very limited as demonstrated by Figure 2. This figure is intended to portray the system costs in millions of dollars per month if we retain the basic structure of the current AUTOVON and are charged as we are today in terms of backbone trunking charges, access line charges, switch charges, and termination charges. The system costs are shown as a function of the number of backbone switches in the CONUS AUTOVON. Note that the backbone trunking and access line charges dominate the total costs and cause the relative "flatness" of the switch, termination, and total costs. What this indicates is that further switch closures will not result in large savings because of the offsetting increases of backbone trunking or access line costs.

Furthermore, switch closures have a major impact on the performance of the network should hostile forces choose to destroy our AUTOVON switches as shown in Figure 3. The abscissa reflects the traffic carried by AUTOVON in an undamaged network while the ordinate reflects the traffic carried by the network when AUTOVON switches are destroyed. Each of the curves represents constant dollars curves, that is, a budgetary limitation of $8.2 million dollars a month as an example. The numbers of switches are varied for this limited budget. Note that there is a tradeoff consideration between the traffic carried in the undamaged network vs damaged network. Each constant cost curve represents a different number of backbone switches destroyed by hostile forces. Note that for this simplified assumption, large penalties may be involved in switch closures while Figure 2 demonstrates limited cost savings in switch closures.

Although the second design approach reflects a low cost-reduction potential in Table II, changes in tariff arrangements could have a large effect on this result. Hence, the second approach should not be dismissed.

TABLE I. DEFINITION OF CONUS AUTOVON ALTERNATIVES

COURSES OF ACTION	NEXT GENERATION CONUS AUTOVON				MACROSCOPIC ATTRIBUTES									
		MOTIVATION			DEDICATED TRUNKING							NON-DEDICATED TRUNKING		
					TERR. NET.		SWITCH TYPES		SWITCH LOCATION		PT-PT			
	DESCRIPTION	COST REDUCTION	NEW TECHNOLOGY & NEW SERVICES	ALT NO.	LG.	SM.	ANA.	DIG.	EXIST.	SUB. LOC.	SATELLITE TRUNKING	PRIVATE LINES SERVICES	WATS	SATELLITE SERVICES (DAMA)
CONTINUE PRESENT APPROACH	MINIMUM UPGRADE	NONE	COMMON CHANNEL SIGNALING	1	X		X		X		X			
	REPLACE SWITCHES	REDUCE SWITCH INVEST.	DIGITAL SWITCHING	2	X			X	X		X			
FOLLOW TELCO DEVELOP-MENTS	COMM'L SERVICES PLUS DEDICATED NETWORK	REDUCE SWITCH. & X-MISSION	TELCO UP-GRADE: NO. 4 ESS	3		X		X	X		X	X		
		MINIMIZE NO. OF SWITCHES	TELCO UP-GRADE: WATS	4		X		X	X		X		X	
NEW ADVANCED CONCEPTS	DISTRIBUTED TERR. NETWORK	REDUCE ACCESS X-MISSION	ON-BASE DIGITAL COMM.	5	X			X		X	X			
	DISTRIB. TERR. NET WITH SAT. IN ACCESS AREAS		NEW SAT. SYSTEM CAPABILITIES W/SM. EARTH TERMS.	6		X		X		X				X

NOTE: The three design approaches are listed under the column heading "COURSES OF ACTION".
The six alternatives are listed under the column heading "DESCRIPTION".
See section IV for detailed discussion.

TABLE II. TEN-YEAR LIFE CYCLE COSTS

DESIGN APPROACH	TEN-YEAR LIFE CYCLE COST* (MILLIONS OF DOLLARS)		ANNUAL COST REDUCTION POTENTIAL
	LOW	HIGH	
CONTINUE PRESENT APPROACH	$1,041	$1,124	17%
FOLLOW TELCO DEVELOPMENTS	$1,130	$1,144	11%**
ADVANCED CONCEPTS	$ 924	$ 939	47%

*Economic worth at beginning of ten year period.

**The relatively low value should not be interpreted to mean that this design approach should be abandoned.

The range between high and low estimates is based on quantifiable uncertainties such as relative inflation rate, digital switch cost, transmission cost and satellite earth terminal cost. However, these estimates do not reflect possible significant changes in tariff arrangements in the second design aproach.

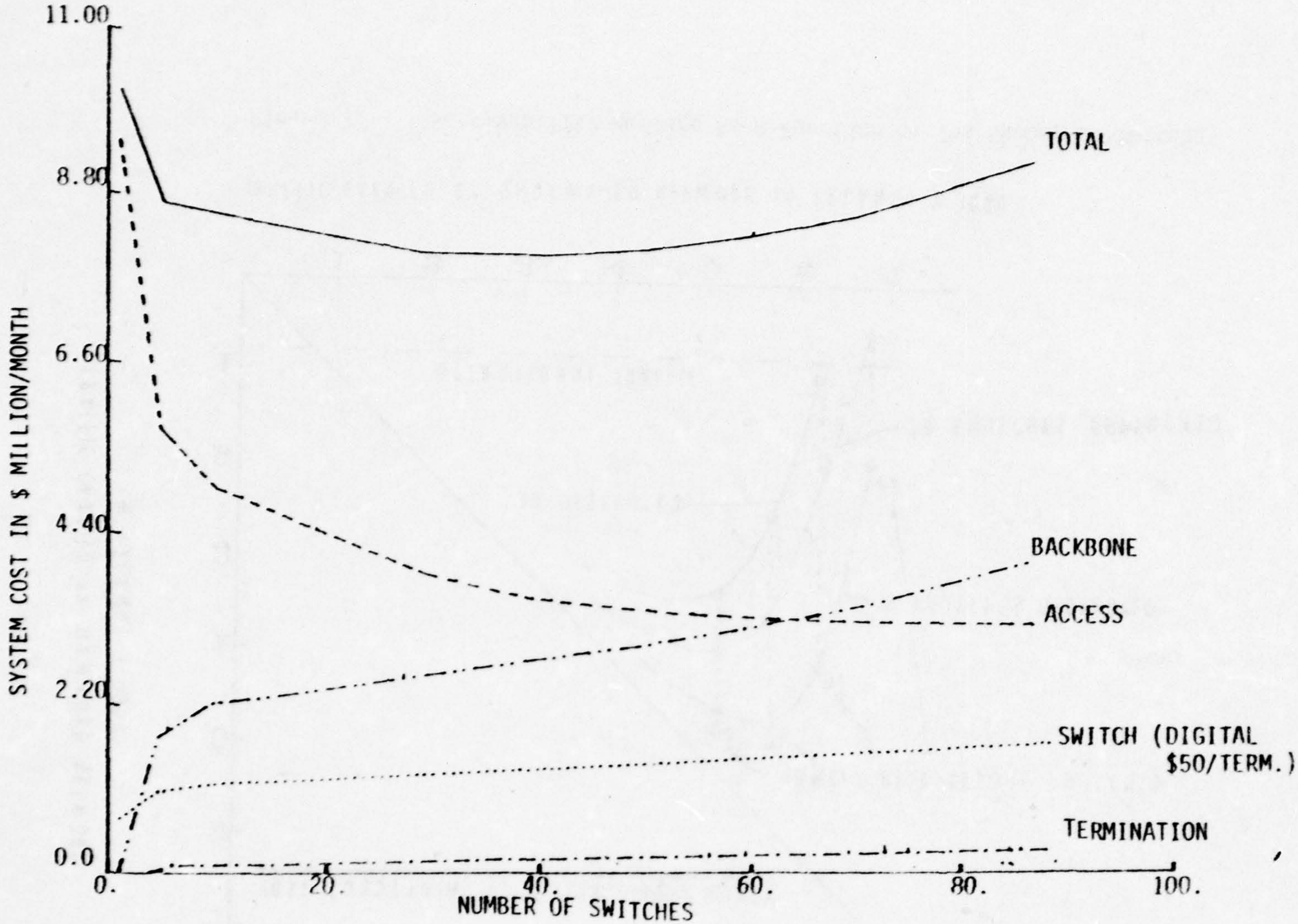


Figure 2. Cost Vs. Number of Switches

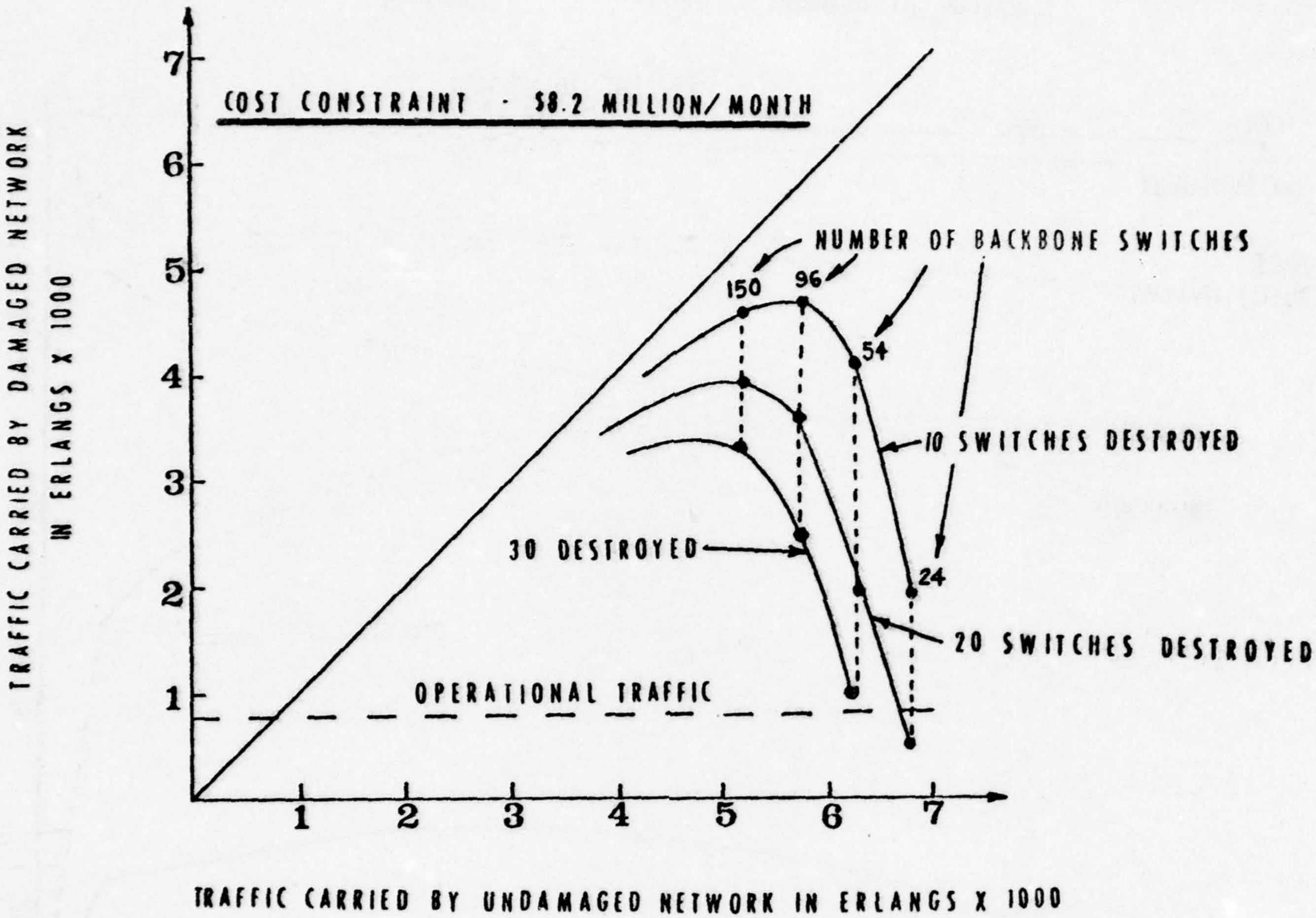


Figure 3. Survivability Measure As A Function of The Number of Switches

Figure 4 is intended to show that the third design approach offers advantages or disadvantages when compared to the first design approach, depending on the scenario. The second design approach cannot be quantified and is omitted from this figure. See section V for a detailed explanation of the figure.

2. Results of the Analysis of Alternatives

The basic results of the analysis of the six alternatives are summarized in Table III and discussed and explained in section V. However, there are some nonquantifiable uncertainties associated with the results on costs which are summarized in Table IV and which should be factored into any decision making process.

Despite the uncertainties, inferences can be drawn which provide insight on the direction to proceed with The Next Generation CONUS AUTOVON. Alternatives 6, 5, and 2 have desirable potential; but so does Alternative 3 if tariff arrangements can be changed, and particularly if Alternative 3 is slightly altered from the specific configuration analyzed.

3. Preferred System Attributes

The preferred system attributes are depicted in Table V. Based on the considerations of section III and section V, then, the following system attributes are considered attractive as of 1978:

- Use of off-the-shelf hardware/software to the maximum extent possible. Special software/firmware may be required for unique applications.
- Lease of available services and facilities to avoid long lead time.
- Multiple homing from a base/facility digital PBX via an AUTOVON mix of media consisting of satellite services, access to the DDD network, T1 tie trunks to other local switches, and T1 interconnects to a regional AUTOVON switch.
- Use of access area software control for least cost routing and DCA software control for operational direction in time of crises.
- Use of management control via automatic message accounting systems.
- Use of digital switches to perform the functions associated with patching, testing, monitoring, and wiring, which eliminates technical controls and terminating facilities.
- Use of new charging arrangements between backbone and access facilities is possible and should be exploited.

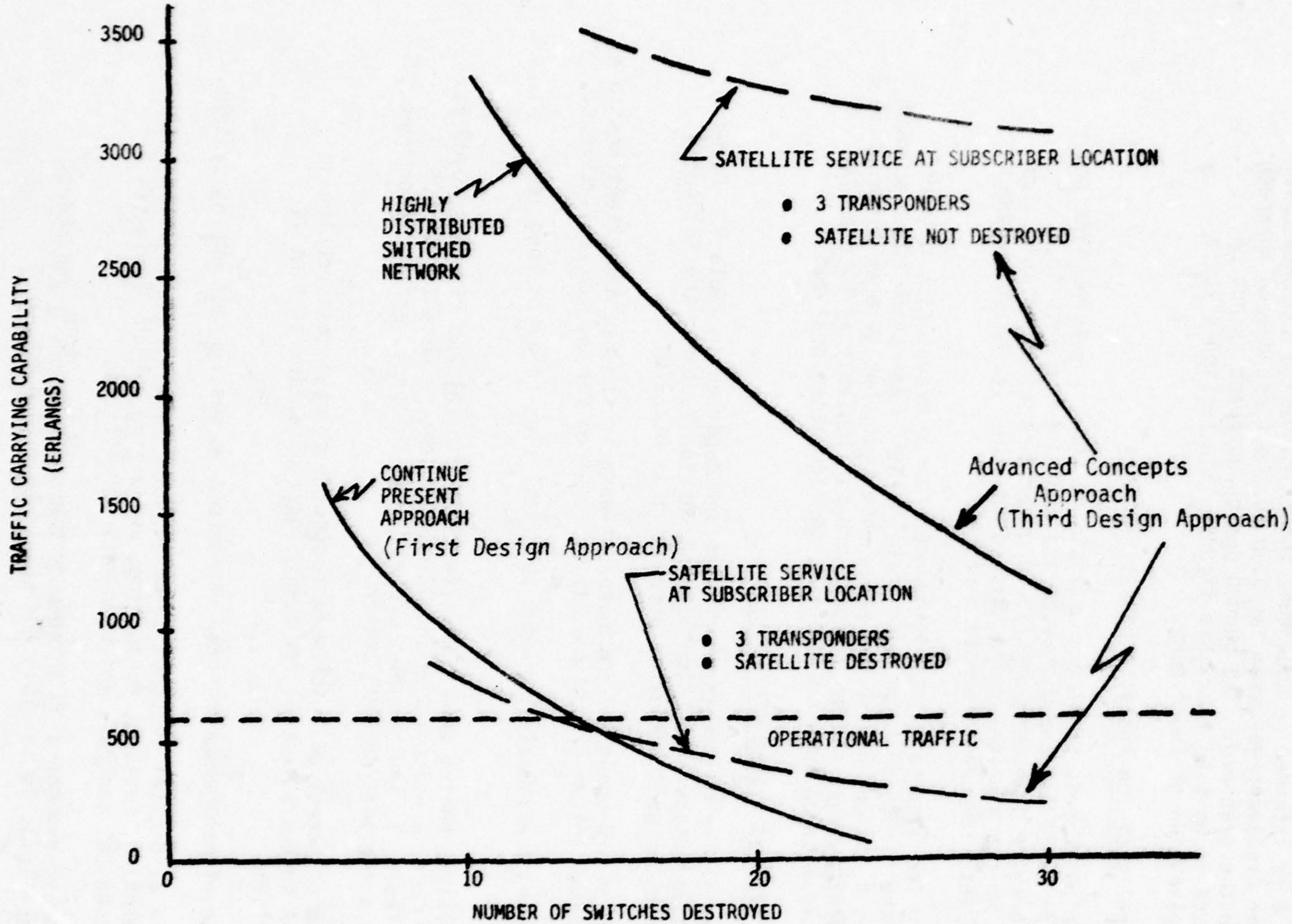


Figure 4. Network Survivability Comparison of Basic Approaches.

The Second Design Approach is omitted because the number of switches in this concept is dependent on the plans of AT&T and the Independents.

TABLE III. SUMMARY OF RESULTS

OPTIONS		CONTINUE PRESENT APPROACH		FOLLOW TELCO DEVELOPMENTS		ADVANCED CONCEPTS	
ALTERNATIVE NO.		1	2	3	4	5	6
COST	ESTIMATED COST/ YEAR IN 1985 DOLLARS (MILLION) (1)	$197	$139	$168	$188	$134	$92
	RANKING OF NOMINAL ESTIMATE	6	3	4	5	2	1
TECHNICAL RISK OF IMPLEMENTATION		LOW	LOW	MODERATE	MODERATE	MODERATE	MODERATE
SURVIVABILITY	COLLATERAL DAMAGE (NUCLEAR)	GOOD	GOOD	FAIR-GOOD	FAIR-GOOD	GOOD	FAIR-GOOD
	DIRECT ATTACK (NUCLEAR & OTHER)	FAIR-GOOD	FAIR - GOOD	FAIR	FAIR	GOOD	FAIR-GOOD

NOTES:
(1) The values listed are nominal estimates. See Appendix C for detailed treatment.
(2) See Appendix D for details.

Ranking is: GOOD
FAIR
MARGINAL
POOR

TABLE IV. NON-QUANTIFIABLE UNCERTAINTIES

UNCERTAINTY	AUTOVON ALTERNATIVES					
	1	2	3	4	5	6
NEW TARIFF/LEASING ARRANGEMENTS	N/A	LEASED DIGITAL SWITCHES AND TRANSMISSION	UTILIZATION RATE OF A SHARED RESOURCE	WATS	LEASED DIGITAL SWITCHES AND TRANSMISSION	LEASED DIGITAL SWITCHES & SATELLITE SERVICE
POLICY CHANGES	N/A		DOD AND JCS POLICY REVISION			
CHANGES IN INTERFACE CRITERIA AND STANDARDS	N/A		FUNCTIONAL/SOFTWARE INTERFACE VS LOCATION/PHYSICAL INTERFACE			
CHANGES IN THE ROLE OF DCA	N/A		OPERATIONAL DIRECTION AND MANAGEMENT CONTROL			
TIME FRAME OF FULL IMPLEMENTATION	BY 1985		POST 1985 - LIMITED BY THE FOREGOING UNCERTAINTIES			
SURVIVABILITY	A SUBJECTIVE EVALUATION HAS BEEN COMPLETED					

TABLE V. PREFERRED ATTRIBUTES BASED ON COST AND SUBJECTIVE ANALYSIS

	CATEGORY	CONTINUE PRESENT APPROACH		FOLLOW TELCO DEVELOPMENT		NEW ADVANCED CONCEPTS	
	ALTERNATIVE NO.	1	2	3	4	5	6
COST COMPARISON	SWITCH TYPE (ANALOG VS. DIGITAL)	-	DIGITAL PREFERRED				
	SWITCH LOCATION		-			LOCATION AT SUBS PREFERRED	
	PT-TO-PT SATELLITE BB TRUNKING VS DEMAND ASSIGNED SERVICE AT SUBS					-	SATELLITE DA PREFERRED
SUBJECTIVE COMPARISON	DIGITAL SWITCHED NETWORK WITH LEAST UNCERTAINTY		TARIFFS AND POLICIES LEAST AFFECTED				
	SURVIVABILITY (DIRECT ATTACK)	FAIR-GOOD	FAIR-GOOD	FAIR	FAIR	GOOD	FAIR-GOOD
	TIMELINESS OF IMPLEMENTATION	EXISTING	PRE 1985	POST 1985	1982-88	POST 1985	POST 1985
	POTENTIAL FOR COST REDUCTION			HIGH, BUT SUBJECT TO REFLECTION IN TARIFFS	POTENTIALLY GOOD	TECHNOLOGY MAY FURTHER REDUCE COST	TECHNOLOGY AND COMPETITION MAY REDUCE IT
	POTENTIAL FOR INTEGRATED SERVICES			GOOD		GOOD	VERY GOOD

VI. PLANNING AND IMPLEMENTATION

The DCEC Technical Report essentially recommends an evolutionary, opportunistic strategy that is keyed to technological developments in commercial telecommunications. The major events in the commercial world relevant to AUTOVON as well as actions which DCA could opportunistically exploit are depicted in Figures 5 and 6 and explained in detail in section VI.

VII. SIGNIFICANT FINDINGS AND CONCLUSIONS

The report closes with a discussion of significant findings and conclusions:

- Because of technical and cost uncertainties, a final architecture cannot be selected at this time. However, two of the six alternatives appear to hold the most promise at this time and it is recommended that DCA pursue an evolutionary transition process which keeps the door open to either of these two variations until the early to mid-1980's when a final decision can be made.

- Alternatives 2 and 3 appear attractive technically but their costs, based on current perceptions of tariffs, are too high. Since they would be based to a large degree on commercial carrier facilities, no immediate major RDT&E expenditures are required under these options. Some effort could be placed in the access area to define the next generation PBX which would provide sufficient "intelligence" in the local area to optimally utilize the commercial facilities.

- Alternatives 5 and 6 appear to offer both technical and cost benefits to the future DCS. DCA should continue to evaluate these options. Selection of these options would raise a number of technical issues, thus requiring an immediate start on addressing these issues so that a highly credible decision can be made in the early to mid-1980's.

- A number of technical design features appear to be applicable to several options and the addressal of these issues should be given first priority. These features are:

  - Deployment of digital PBX's capable of serving both voice and data requirements and which are compatible with U.S. commercial analog and T-1 digital services. Such PBX's will place network "intelligence" (e.g., routing, precedence/preemption, and control) at the local level vice the backbone switches.

  - Exploitation, through the use of such PBX's, of the extensive commercial networks by use of dialed-up PBX-to-PBX connections

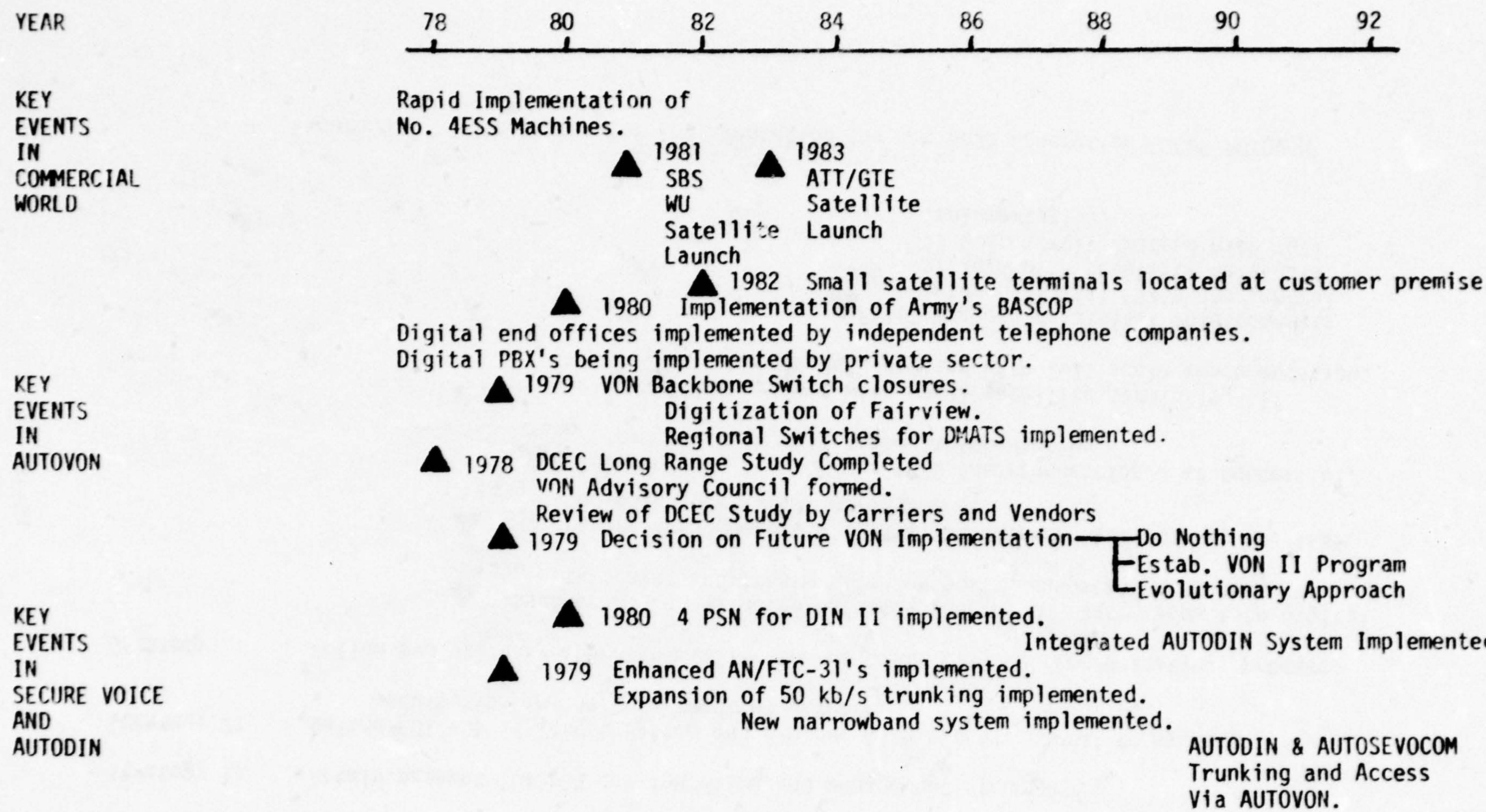


Figure 5. Major Events Relevant to the Next Generation CONUS AUTOVON in the Time Frame Up to 1992.

YEAR 78 80 82 84 86 88 90 92

DCEC study completed.
VON Advisory Council review completed.
Review by carriers and vendors completed.

Strategy 1: Retain present AUTOVON configuration and management structure.

Strategy 2: Define AUTOVON II Target System and proceed with process normal to systems acquisition in the Department of Defense.

Strategy 3: Follow evolutionary approach similar to the commercial telecommunications process.

▲ 1979 Issuance of Consolidated Guidance (CG) by DoD with respect to digital switching and transmission on posts, camps and stations.

▲ 1979 Exploratory arrangements with AT&T on interconnection with No. 4ESS including new tariff arrangements.

▲ 1980 Pilot projects for VON/No. 4ESS interconnection. If successful, proceed with full scale implementation.

▲ 1982 Pilot project with small satellite terminals. If successful, proceed with full scale implementation.

▲ 1985 Pilot project on digital interconnects between digital PBX's and central offices with satellite terminals. If successful, proceed with full implementation.

Figure 6. Strategies for Implementation for the Next Generation CONUS AUTOVON

vice private line/dedicated connections, thereby allowing dynamic reconfiguration of the backbone and potentially leading to increased survivability/flexibility.

- Exploitation of commercial multipoint satellite services to reduce overall costs.

I. INTRODUCTION

1. PURPOSE

Because of the rapidly increasing tariff charges to the Department of Defense for CONUS AUTOVON services as a result of changes in the U.S. regulatory environment, the Director, DCA requested that alternatives for the future of AUTOVON be considered as part of DCA's ten year planning efforts.

The purpose of this Technical Report is to document the results of studies, seminars and analyses performed or held at the Defense Communications Engineering Center (DCEC) in response to that request, including the following:

(1) Review of developments in commercial telecommunications relevant to the future of CONUS AUTOVON.

(2) Description and quantitative analysis of six alternatives postulated for the Next Generation CONUS AUTOVON (AUTOVON II) in order to gain an understanding of the dominant and sensitive factors which influence cost and survivability.

(3) Description of a concept and strategy for evolution to the Next Generation CONUS AUTOVON (AUTOVON II) based on both quantitative and qualitative analyses of items (1) and (2).

2. SCOPE

The CONUS AUTOVON is part of a global AUTOVON network which includes the Canadian Switched Network (CSN) and the Overseas AUTOVON. The scope of this Technical Report is limited to the CONUS AUTOVON within the contiguous 48 states which is sensitive to changes in the U.S. regulatory environment.

CONUS AUTOVON is a tariffed offering by American commercial carriers within the contiguous United States. As such, it is categorized under Private-Line Offerings of the American carriers which also includes Selective Signaling systems, tandem tie-trunk networks, common-control switching arrangments (CCSA), the Joint Chiefs of Staff Alerting Network (JCSAN), and other command post alerting networks.

AUTOVON is a worldwide circuit-switched network for telephone and data transmission serving the Department of Defense and other authorized users. The network serves a broad spectrum of traffic ranging from critical command and control communications to administrative calls. It also provides narrowband trunking service for the AUTOSEVOCOM (Automatic Secure Voice Communications Network) and alternate trunking service for AUTODIN (Automatic Digital Network).

The time frame covered by this technical report is defined by the DCS Plan FY 82-92.

3. ORGANIZATION OF THE REPORT

Section I is an introductory discussion of the purpose, scope of effort, and the organization of the report.

Section II provides a background on the motivations for the preparation of this Technical Report.

By policy, the DCS in CONUS is leased from commercial and special carriers wherever they can provide the service. Section III considers the technological improvements anticipated among commercial telecommunications carriers from whom the Next Generation CONUS AUTOVON must be leased in the 1982-1992 time frame.

Section IV describes the alternatives open to the DCA developed by consensus at DCEC and staffed through the Headquarters, DCA, including the Director. Essentially three concepts are considered:

- Retaining the current backbone and the polygrid routing.
- Adapting to new developments among telephone companies.
- Creating a new CONUS AUTOVON based on advanced concepts.

Most of the effort of the DCEC study was concentrated on a quantitative analysis of the postulated alternatives. Section V provides a summary of these essential topics, whereas the details are furnished in separate appendixes.

Section VI considers implementation strategies for AUTOVON II in the 1982-1992 time frame and takes cognizance of the changing regulatory, legal, and competitive environment of the next decade.

Section VII considers the significant findings and recommendations of this report.

The appendixes provide the detailed quantitative analysis of the study and represent an essential part of the document to which the DCEC effort was concentrated. The topics considered are:

- AUTOVON II Requirements
- Common Channel Signaling (CCS) and AUTOVON Routing Philosophy
- Network Design and Economic Analysis

- Survivability

- Network Management Implications

- Attributes of The Next Generation CONUS AUTOVON

- Policies

4. RELATIONSHIP TO OTHER DOCUMENTS

This Technical Report is one of several documents prepared by the Defense Communications Engineering Center in support of The DCS Plan FY 82-92 to be published by the DCA in May, 1979.

Other documents and Technical Reports prepared concurrently with this Technical Report cover the entire spectrum of planning of the global DCS including transmission systems, switched networks, and support systems in the FY 82-92 time frame. They include:

TR 19-78	The Baseline DCS, FY 82
TR 20-78	The DCS, FY 82 and Beyond
TR 21-78	DCS III Architecture And Advanced Systems Concepts

The DCS Plan is published every two years by the Defense Communications Agency to document long term (ten-year) planning. The vehicle for obtaining programming funds for plans approved for programming is the DCS Five Year Program (FYP) which includes minor DCS projects and programs as well as the major programs sponsored by the DCA.

The DCA is also currently engaged in architectural studies which go beyond the traditional purview of the DCS. These studies will influence future DCS ten year plans.

II. BACKGROUND

1. HISTORY OF CONUS AUTOVON

As recently as the early 1960's, long distance military telecommunications were connected via manual switchboards. In 1956, the U.S. Army planned a network of leased four-wire automatic switches on military posts in CONUS. As an interim solution, the AT&T furnished a network of manually operated 5D toll switchboards in four cities, with plans to develop an automatic four-wire switch. This manual system functioned until December 29, 1961, when it was replaced by the four-wire No. 5 Crossbar automatic machines into a network called the Signal Corps Alerting Network. The tariff arrangements developed during this period, as well as similar arrangements developed with the U.S. Air Force for NORAD/ADC long distance switching networks, evolved into the Switched Circuit Automatic Network (SCAN) Tariff Arrangement by which the U.S. Government leases automatic switches from the commercial carriers.

On April 19, 1964, the CONUS AUTOVON was established by combining the Signal Corps Alerting Network and the U.S. Air Force NORAD/ADC Networks into a single network. Coincident with the merger, the AUTOVON-unique feature called Multi-Level Precedence and Preemption (MLPP) and Polygrid Routing (as opposed to the commercial hierarchical routing) were implemented. Private line offerings of the carriers were utilized for tariff arrangements for interswitch trunks and access lines.

The leased switches consist of No. 1 ESS (Electronic Switching System) and some original No. 5 Crossbar machines from AT&T, and a newer version of the Overseas AUTOVON Switch manufactured by Automatic Electric Company which provides service for the Independent Telephone Companies.

The current CONUS AUTOVON was developed with technologies and network approaches that are now obsolete. At the time the network was conceived, extra terminations were included in the AUTOVON switches to accomodate future growth.

Over the years, the projected growth of communications requirements has not materialized to the extent originally forecast. At its peak size, CONUS AUTOVON had 60 switching centers. However, switch reductions were possible because improved cost minimization algorithms showed that the polygrid system with 60 switches could be replaced with less cost and equal survivability with 51 switches with less trunk interconnections but more multiple homing of critical subscribers. Furthermore, for reasons discussed below, 6 of the current AT&T switches are programmed for removal, which will leave a total of 45 switches in the CONUS.

2. CHANGES TO TARIFFING ARRANGEMENTS

a. SCAN Tariff. SCAN, an offering of the Bell System since December 1961, is an interstate private-line offering which was designed to meet the essential communications needs of two governmental agencies: The Department of Defense (DoD) and the General Services Administration (GSA). The switching arrangements and associated features furnished under the SCAN offering are an integral part of these two agencies' communications networks: DoD's AUTOVON and GSA's Federal Telecommunications System (FTS).

There are two categories of SCAN tariff offerings: System A (SCAN-A), which applies to the FTS (in combination with Common Control Switching Arrangements or CCSA), and System B which is relevant to AUTOVON. System B (SCAN-B) provides for the switching of private-line voice-grade communications channels and various other private line channels. Various features designed to meet the unique requirements of the DoD include multilevel precedence preemptions, service switchboard arrangements, automatic and rotary conferencing arrangements, off-hook service, and abbreviated keying arrangemments.

It was found mutually beneficial to AT&T and the DoD to remove eight CONUS switching centers from the AUTOVON network during the 1975-1976 period and to reterminate the access lines on other AUTOVON switching centers. Nevertheless, the SCAN arrangements presently in service are still underutilized by about 60 percent, adversely affecting the return on investment (Figure II-1).

On October 1, 1976, the Federal Communications Commission released the Commission's Order in Docket No. 18128 which required that the rates for SCAN produce a ratio of net operating earnings (NOE) to net investment of 9.5 percent in accordance with revised Fully Distributed Cost Method 7 (FDC-7) Procedures.

According to AT&T's study of a 12-month period ending December 31, 1976, the additional gross operating revenues needed to achieve an earnings ratio of 9.5 percent amounted to $24 million. Computations made by the Defense Communications Agency's Operations Directorate indicate that the impact on AUTOVON alone would be 16 million dollars.

AT&T's response to the Commission proposed the following steps to achieve a 9.5 percent earnings ratio by 1979:

Step 1 — 1977 - Effective October 13, 1977, an increase in individual SCAN rate elements of 20 percent together with certain changes in the application of charges for channel terminations. (Actually took effect on October 28, 1977.)

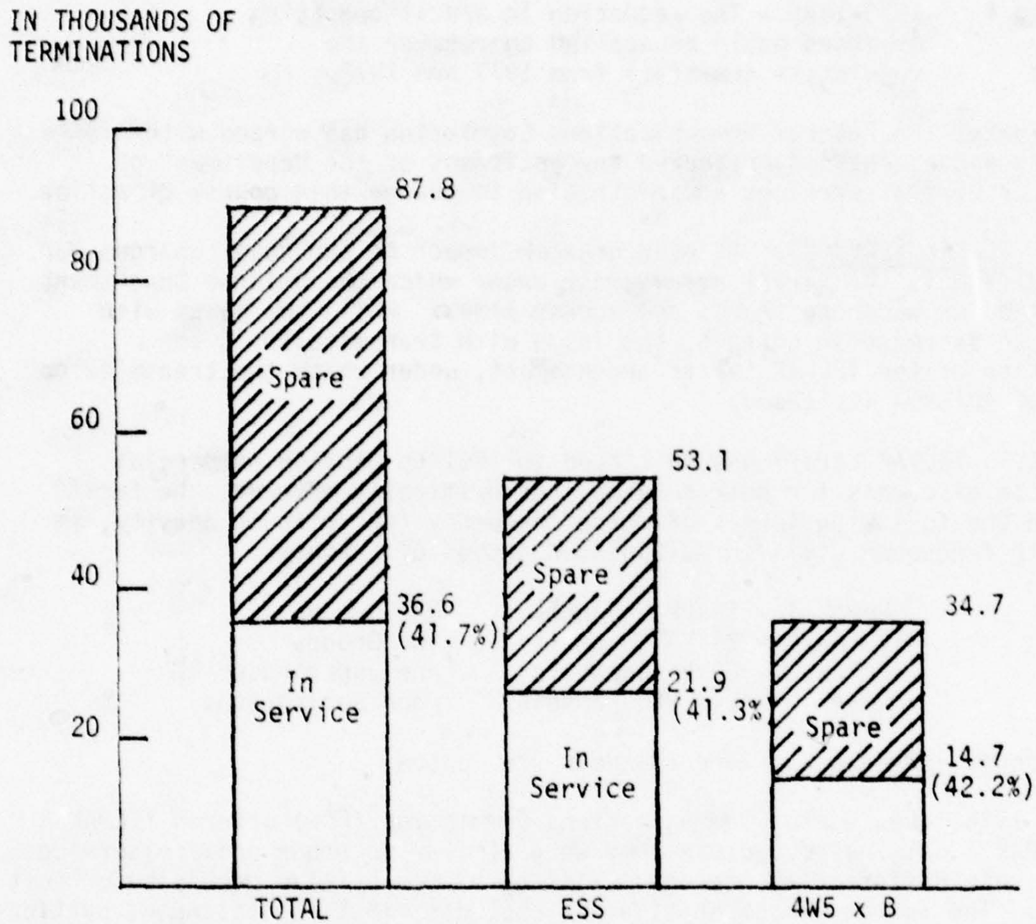


Figure II-1. SCAN Switch Utilization (Including AUTOVON and FTS.)

Step 2	1978 - An increase in individual rate elements of approximately 35 percent to be effective 12 months after the 1977 increase.
Step 3	1977-1979 - Removal of 10 CONUS AUTOVON switches. (Subsequently, it was agreed to remove 6.)
Step 4	1979-1985 - The reduction in annual operating expenses would be applied to recover the cumulative shortfall from 1977 and 1978.

To date, the Federal Communications Commission has agreed with AT&T's proposals and essentially rejected any petitions of the Department of Defense or General Services Administration to change this course of action.

b. TELPAK SERVICES. Of even greater impact to the total charges for CONUS AUTOVON is the tariff arrangement under which the Defense Department is charged for backbone trunks and access lines. While the issue with SCAN is an increase in charges, the issue with transmission is the elimination of the TELPAK tariff arrangement, under which the transmission for CONUS AUTOVON is leased.

AT&T's TELPAK tariff was initiated in 1961 to provide commercial users with discounts for bulk service. As originally offered, the tariff provided the following levels of voice frequency (VF) circuit density, in line with frequency division multiplexed groups of channels:

TELPAK A - 12 VF Channels	One Group
TELPAK B - 24 VF Channels	Two Groups
TELPAK C - 60 VF Channels	One Supergroup
TELPAK D - 240 VF Channels	Four Supergroups

The discount increases as more channels are leased.

In 1976, the Federal Communications Commission (FCC) ordered TELPAK A and TELPAK B eliminated because they were similar to other private services and the rate differential was not justified by competitive necessity or cost savings. The issues of competition and cost distribution continued, particularly in light of the finding that the TELPAK earnings to investment ratio was only 0.3 percent, far below the targeted ratio of 9.5 percent. The FCC concluded that:

- TELPAK rates were discriminatory.
- TELPAK was not a competitive response.
- Other bulk rates may be justified.

In early 1977, the AT&T withdrew its TELPAK offering. This withdrawal was complicated by another issue: the resale of transmission facilities by a third party. Essentially, a third party could procure transmission facilities at substantial savings through TELPAK and provide new services, effectively competing with AT&T in the lucrative segments of the market.

The withdrawal of TELPAK has been the subject of a number of petitions by its users. In July 1977, the D.C. Court of Appeals issued an injunction on the discontinuation of TELPAK. This resulted in the continuation of the TELPAK arrangement to those users of record. TELPAK, however, is denied to new users.

How long this arrangement will continue is not known. The AT&T has filed for a Multi-schedule Private Line (MPL) Arrangement categorized under Tariff 260 to become effective upon the demise of TELPAK.

c. Impact To CONUS AUTOVON Costs. Prior to October 1977, the total annual charges for CONUS AUTOVON amounted to approximately $100 million. Figure II-2 indicates the breakdown of this total figure into those portions attributable to the switching centers under the present SCAN tariff and the transmission costs for interswitch trunking and access lines under the TELPAK offerings.

The figure also indicates the impact to these network components under the new SCAN charges and proposed MPL tariffs, which would result in a $46 million annual increase in current dollars.

3. THE CHANGING TECHNOLOGY

The present network is over 10 years old and the total Basic Termination Liability on most of the CONUS AUTOVON switching centers will expire by May 1980. Because the SCAN charges are based on the original investment of the switches, rearrangements to the network with new switches would not have the impact to the DoD as they would have had a few years ago. With continuing technological advances in switching and transmission equipment, the investment in new facilities has dropped compared to the original investment for AUTOVON switches. These technological advances are discussed in greater detail in section III of this Technical Report.

4. THE DIRECTOR'S REQUEST FOR THE STUDY

Because of the realities noted above, The Director DCA, in April, 1977, requested that alternatives for the future CONUS AUTOVON be explored. For the near term, the Operations Directorate and the Defense Communications Engineering Center conducted studies which resulted in the planned closure of six AUTOVON switches. Other near term alternatives are still being investigated by the Operations Directorate.

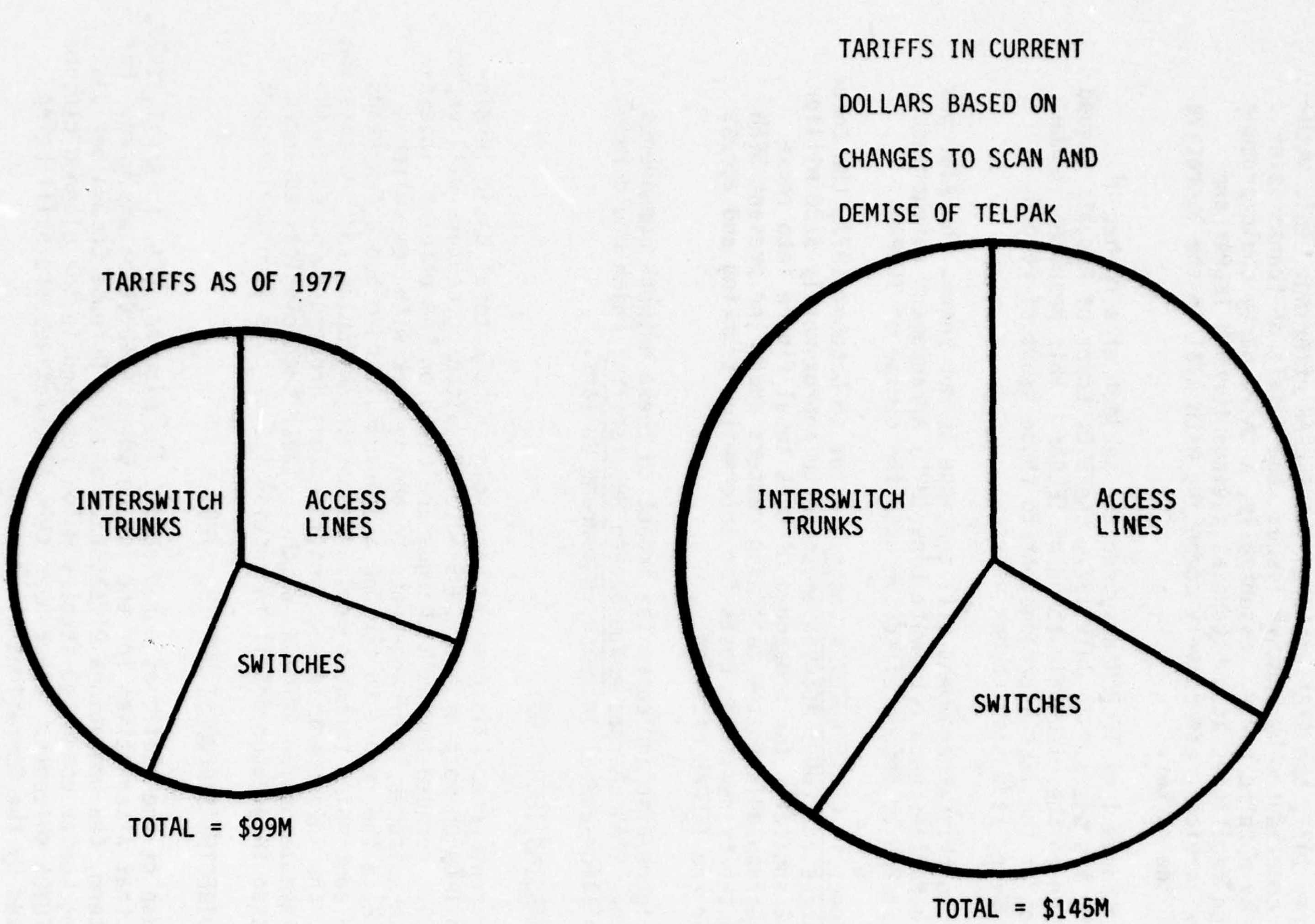


Figure II-2. CONUS/CSN Annual Costs

The request for the long term studies was made in a review of the DCS ten year planning efforts. The Director's request called for alternatives such as a future AUTOVON which consisted of traveling class marks in a network of No. 4 ESS's or which utilized the services of new satellite carriers. The request was made to the Plans and Programs Directorate which subsequently requested that the Defense Communications Engineering Center perform the necessary studies as part of the planning support for publishing The DCS Plan FY 82-92.

The Defense Communications Engineering Center has held several seminars relevant to the problem and formulated six alternatives for the future which were staffed through the various divisions of DCEC and Headquarters, DCA. The six alternatives were approved for analysis by the Director, DCA, in February, 1978.

III. IMPLICATIONS OF TECHNOLOGICAL DEVELOPMENTS

1. COMMERCIAL TELECOMMUNICATIONS

By Department of Defense (DoD) policy, the Defense Communications System in the Continental United States (CONUS) has consisted of leased facilities or services wherever the private sector and the common carriers can provide the service [1]. U.S. Government owned facilities are the exception rather than the rule except for unique and vital requirements. Therefore, in considering the next generation AUTOVON in CONUS, it is important to consider the technological developments in commercial telecommunications. The developments considered here are restricted to what the common and specialized carriers are planning for the decade 1982 to 1992. Advanced "state of the art techniques" which depend on technological breakthroughs, and for which no commitments are made by carriers, are not considered.

The American Telephone and Telegraph (AT&T) Company is a dominant element in commercial telecommunications and its technological developments should not be ignored in considering the future of AUTOVON. Indeed, the present AUTOVON in CONUS is leased from AT&T and the Independent Telephone Companies and many of the network management functions are performed by AT&T for DCA and the U.S. Government. The following subsection on terrestrial transmission improvements is primarily oriented toward developments in AT&T transmission systems. Subsequent paragraphs on switching systems and domestic satellite communications consider the emerging telecommunications capabilities of the independent and specialized carriers as well as those of AT&T.

a. Terrestrial Transmission Systems. In today's AUTOVON, the dominant charges to DCA and the DoD consist of backbone and access line charges, and the cost of transmission is an important consideration in the tariff charged to the DoD. It is assumed that the TELPAK tariff will be discontinued and that future charges to DCA, based on Multi-schedule Private Line (MPL) rates, will substantially increase backbone charges and access line charges. Hence it is instructive to review developments in transmission which could impact AUTOVON.

Historically, the AT&T Long Lines investment per circuit mile has been dropping and, as recently as 1975, that investment per circuit mile was one fourth as high as it was in 1945 [2] (see Figure III-1). The trend is expected to continue for the reasons discussed below. These trends, however, will not necessarily be reflected in reduced AUTOVON backbone and access line charges unless new tariff arrangements are made. However, the reasons for the descending cost trends should be examined in

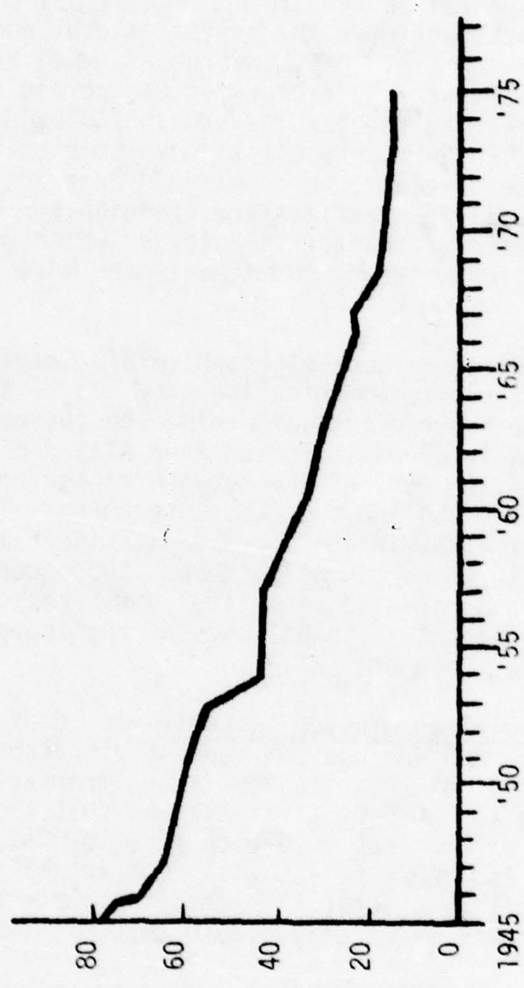


Figure III-1. AT&T Long Lines Investment Per Circuit Mile

order to consider how the U.S. Government could possibly adapt AUTOVON to share or exploit the lower costs of long haul transmission.

The technical reasons for the downward trend in the long haul investment per circuit mile are embodied in the changing nature of the AT&T's transmission carrier facilities. In 1940, long haul circuits were dominated by cable. In the next two decades, the introduction of radio relay and coaxial cable transmission technology led to such economies in multichannel transmission that by 1976 they became the exclusive means for long distance terrestrial transmission [2] (see Figure III-2).

A dramatic increase in capacity of the TD-2 microwave line-of-sight systems used by AT&T in long haul transmission was achieved with no increase in the frequency spectrum and without significant increases in maintenance and operational personnel. In 1950, with vacuum tube technology, approximately 2,400 circuits could be carried per link. By 1976, the capacity had increased nine-fold by the technological improvements indicated in Figure III-3. AT&T foresees additional capacity increases by exploiting single sideband (SSB) radio techniques as opposed to the present frequency modulation (FM) techniques [2]. Before 1982 (the baseline year for The DCA Plan FY 82-92), a two-to-three-fold increase in capacity is achievable. It would be safe to conclude that the downward trend in investment per circuit mile will continue into the early 1980's.

Of relevance to DCA is that the use of SSB technology implies that much of the long-haul intercity toll trunks will remain analog through the 1980's. A digital transmission capability also exists on each radio channel via a Data In The Middle (DIM) system which provides a 3 Mb/s digital channel without displacement of any voice circuits. These DIM systems are meant for data services and should not be misconstrued as available digital lines for intercity toll trunks.

Short haul transmission (intra-metropolitan areas) has also experienced technological improvements and a decrease in per circuit mile investment costs. The T1 digital transmission system (24 PCM voice circuits) was developed to obtain greater channel capacity from existing cables, and thereby reduce the costs and complexities of adding cables and conduits in metropolitan areas. A new T1C system provides twice the capacity of the T1 system over the same cables. These systems are rapidly leading toward an interoffice digital world in metropolitan areas. To enhance this trend, costs for fiber optic cables and their associated connectors are rapidly approaching those of conventional electrical wire and connectors [3]. All optical systems currently being developed and tested by the Bell System are digital and these high capacity systems are expected to begin limited service in the early 1980's.

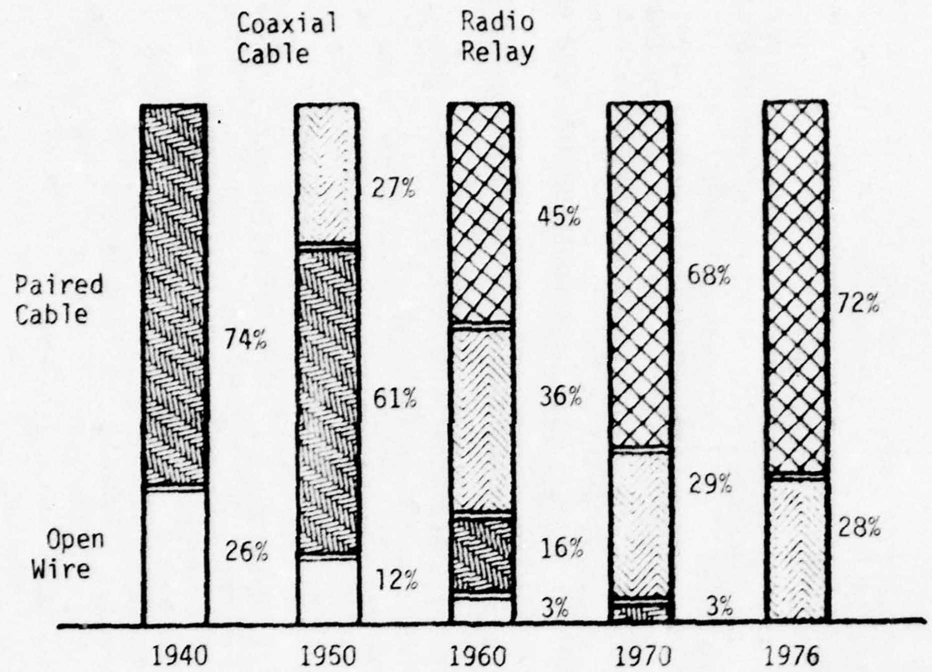


Figure III-2. The Changing Technology in AT&T's Long Lines Transmission Carrier Facilities

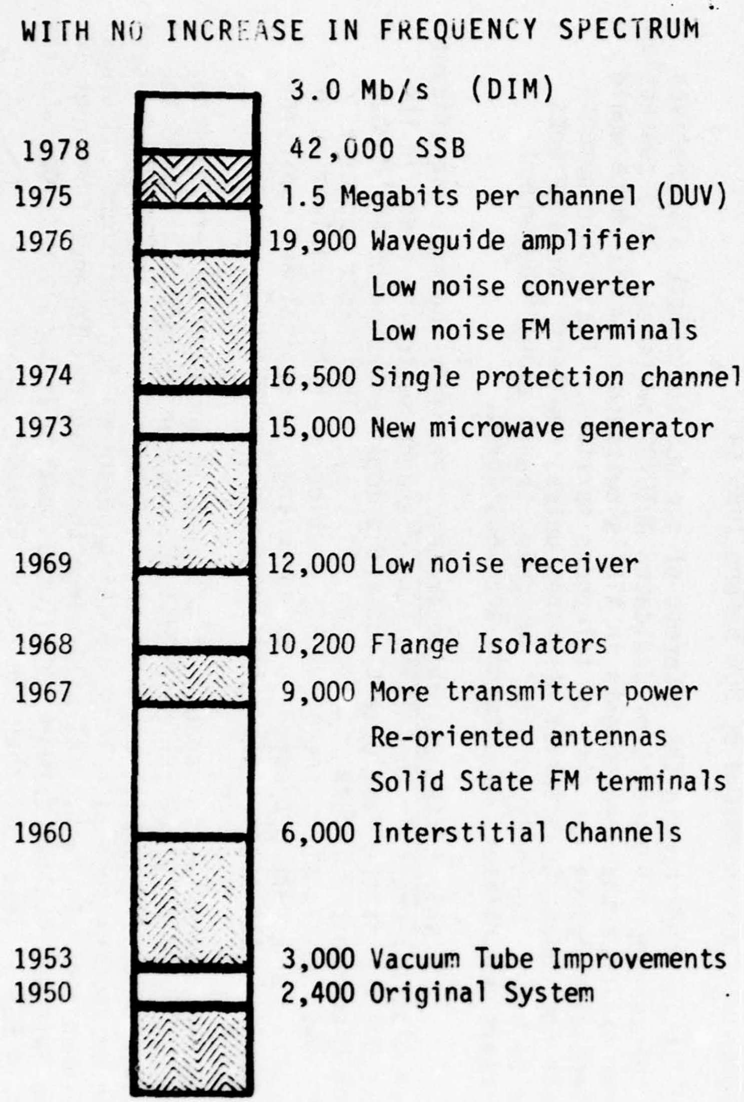


Figure III-3. Increasing Capacity on AT&T's Long Lines TD-2 Microwave System

The terrestrial transmission environment of the 1980's will consist predominantly of AT&T communications resources with the major attributes of high capacity digital transmission in metropolitan areas and economical long haul transmission (predominantly analog). This terrestrial environment will be augmented by digital satellite communications and the introduction of local office digital switches (in addition to the No. 4 ESS toll switches), both of which will be discussed in subsequent paragraphs.

b. Switching Systems. In addition to the backbone and access lines leased from the commercial carriers, the current CONUS AUTOVON consists of No. 1 ESS and No. 5 Crossbar (5XB) switches which are dedicated for AUTOVON and leased from AT&T and independent telephone companies. The tariff offering is called Switched Circuit Automatic Network (SCAN) System B. As a result of The Federal Communications Commission's Order in Docket No. 18128 released October 1, 1976, the SCAN tariff offering for AUTOVON will be increased by 80% before 1985 [4].

It is therefore in the interest of the DoD to explore alternatives to the current arrangement of dedicated AUTOVON switches. This subsection first explores the developments in AT&T's switched networks which would potentially reduce the cost of telephone services. These developments would not reduce SCAN tariff offerings unless new tariff arrangements can be made. Secondly, digital switching trends among independent carriers and Military Departments are considered.

(1) Bell System Switching Trends. Probably the most significant technological event in the AT&T's long distance switching scene in the last 5 years is the development and rapid implementation of the Number Four Electronic Switching System (No. 4 ESS). The larger capacity and lower unit cost of the No. 4 ESS combined with the efficiencies of digital trunks are projected to bring savings in capital and operating expenses in the order of $1.5 billion a year by 1985 [2].

The new system is capable of a five-fold increase in terminations, can handle eight times the offered load, and can perform four times the number of call attempts, as indicated in Figure III-4. All the increases can be accomplished with less operating personnel for equipment and trunk maintenance. In fact, AT&T will merge these two maintenance functions in the Switched Digital Network (SDN), thus making it possible to operate the No. 4 ESS at less cost than the No. 4A Crossbar [5].

The No. 4 ESS is a time division switch employing stored program control, common channel signaling, time-slot interchange units, and a digital matrix. The basic interface is a T1 carrier format which forms the basis for the time-slot interchange method of switching.

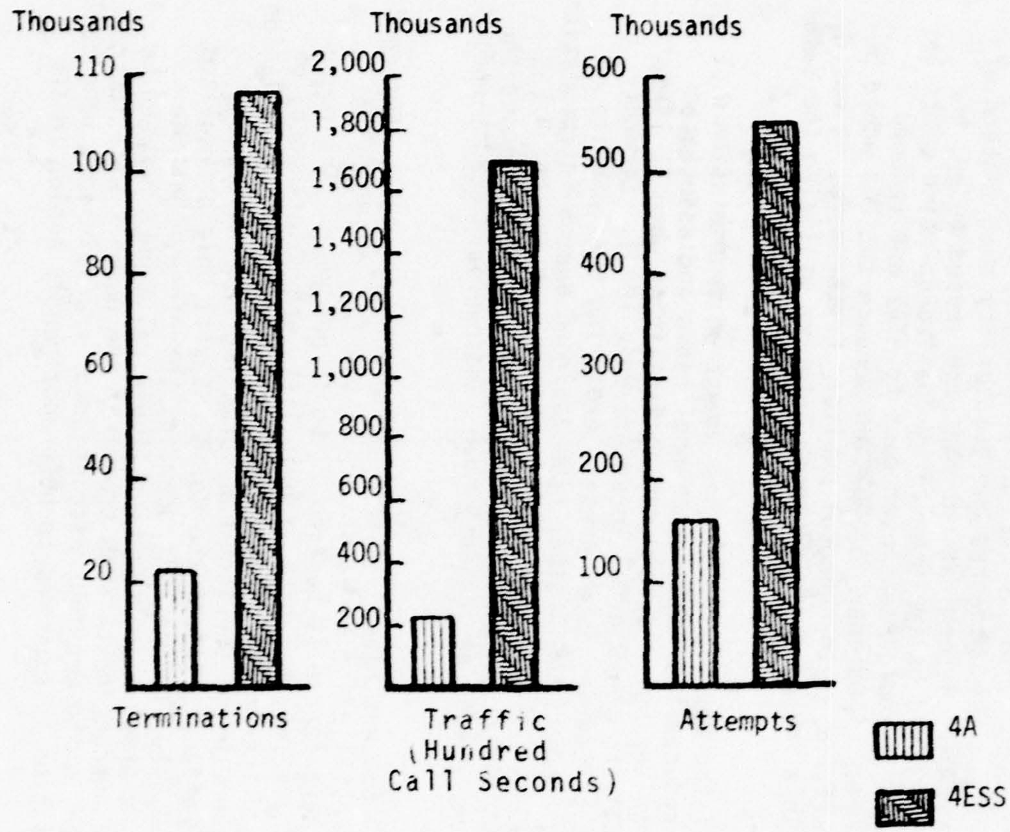


Figure III-4. Comparison of Capabilities-- No. 4A Crossbar Vs. No. 4 ESS.

The time slots are used for telephone service in a way analogous to the service offered to the general public (but not AUTOVON) with the No. 4A Crossbar Switches. With the No. 4 ESS, however, a particular time slot carries Digital Data Service (DDS) traffic which could be used for AUTODIN traffic and secure voice while sharing the resources of the general public. Another time slot carries Dataphone Switched Digital Service (DSDS). In today's Dataphone service, rates up to 9.6 kb/s are available in contrast to DSDS where up to 56 kilobits could be made available over a voice time slot (a more than five-fold increase in capacity) with better error performance. A time slot can also be designated as "private line" which is the tariff category under which the present AUTOVON fits. This broaches the possibility that instead of the dedicated lines and switch terminations that are leased today, the future AUTOVON trunking could be implemented by "nailed up" time slots by the No. 4 ESS machine. It could mean lower cost to AT&T and reduced charges to the Department of Defense for AUTOVON because the DCS would be sharing the same facilities as the general public. Furthermore, it would be possible to similarly route Special Purpose Networks utilizing the same technique.

The potential of the No. 4 ESS also has impact on transmission systems. First, it reduces the need for channel banks and associated patching, testing, monitoring, and terminating facilities when T1 lines are interfaced directly to the Digital Interface Unit (DIU). Secondly, the Bell Telephone Laboratories is at present exploring the benefits of variable rate digital coding and digital time assigned speech interpolation (TASI-D) techniques. Such techniques, when combined with the No. 4 ESS and the Time Slot Optimizer (implementation for TASI-D), could reduce the trunks or access lines needed during busy hour (and overload conditions) by a factor of four.

The first No. 4 ESS was placed in service in January, 1976. Switches are expected to be installed in 87 locations by the end of 1982. The installation rate thereafter will be from 12 to 15 per year. The operational advantages (primarily capacity, flexibility, and maintenance) of digital switching and the economic advantages have forced the installation of these switches even though the long haul trunking remains analog. However, the larger efficiencies of the No. 4 ESS will only be realized through the use of digital trunks. It appears, therefore, that the 1980's will bring the gradual introduction of digital trunks between No. 4 ESS's, and that the percentage of such trunks in the network will increase each year. As noted in the previous discussion of transmission, long haul terrestrial transmission is expected to be predominantly analog in the 1980's.

The AT&T Company originally intended an evolution to the Digital Switched Network (DSN) from the high end of the hierarchy. However, the recent development of economical Class 5 digital switches and PBX's has motivated the Independent carriers to take advantage of the benefits and economics of the new technology [5]. For similar reasons, AT&T is now embarking on the development of its own Class 5 digital switch. The AT&T trend is towards a digital switched network (Class 5 switches and No. 4 ESS's) with predominantly digital transmission in local metropolitan areas and, eventually, digital long haul trunks.

A possible scenario within this telecommunications environment could evolve where all AUTOVON, AUTODIN, secure voice and Special Purpose traffic (subscriber to subscriber) would be carried via time slots either nailed up or with traveling class marks. The DCA could then be charged for the fraction of time slots utilized relative to the total time slots available. Hardware investment costs would be shared with the general public. Software investment costs would depend on the features required by the user.

(2) Switching Trends Among Independent Carriers and Military Departments. The successful activation of the No. 4 ESS in Chicago, Illinois by AT&T in January, 1976 heralded a new era for the Direct Distance Dialing system and the "high end" of the telephone switching hierarchy. In the same year, three manufacturers announced product lines for digital Class 5 offices for the lower "end offices" of the hierarchy, triggering what may eventually be as significant to telephony as the No. 4 ESS. These developments have directly influenced AUTOVON itself and the DCA is currently considering a digital version of the AUTOVON switch at Fairview, Kansas [6]. Other Independents associated with AUTOVON are also interested in conversion to digital operation.

The impact of digital switching technology developments at the lower end of the hierarchy will undoubtedly impact future access to AUTOVON as well as AUTOVON itself. The marketplace apparently views the advantages of digital switching not only in terms of switching but in terms of integrated transmission and switching. The tremendous success of PCM carrier for interexchange and toll connecting transmission, as opposed to normal cable operation or FDM carrier facilities, and its use even in subscriber carrier applications have made it possible to integrate the T1 lines with digital switches.

The pitfalls of a digital loop plant and the 2-wire to 4-wire conversion are being solved. One advantage of a digital office over the conventional analog office is that each digital switch has incorporated provisions for a remote subscriber switch which is an extension of the central office. At least one vendor has enjoyed immense success with a

digital PBX (private branch exchange) which can easily and economically be used as a remote office connected with T1 lines. Note that conversion of much of the short haul transmission facilities to T1 carrier and the success of digital PBX's in penetrating the market are motives for using the remote office with a T1 interface to the Class 5 Office. The provision for the remote office or PBX by digital switch manufacturers makes cost savings due to integrated transmission and switching a strong argument for the independent carriers to move into the digital world.

The cost savings involved when digital transmission and switching are combined can be attributed to the elimination of channel banks, toll terminal equipment, and trunk relays. Additionally, patching, testing, and monitoring facilities associated with channel banks and toll terminal equipment are no longer necessary.

Among the Military Departments, the U.S. Army has taken the lead in exploiting the new technological developments in commercial telecommunications by constructing an overall plan called BASe COmmunications Plan (BASCOP) [7]. BASCOP will be annually updated to provide a structure or "umbrella" under which all Army post-camp-station communications will be upgraded. This structure has the form of integrated digital transmission and switching with the use of a remote switching unit (RSU) or PBX tied to the main PBX (or central office) with a T1 line, instead of separate cable pairs carrying individual telephone calls. The advantages of this architecture are summarized in Table III-I [7].

The implications of the technological developments relevant to the Independents and the manufacturers who cater to this market are twofold. First, an increasing number of AUTOVON users will be converting to digital PBX's. Secondly, the Independents who provide AUTOVON (including our Canadian counterparts) will have compelling economic pressures to convert their AUTOVON switches to digital operation.

Such a digital bandwagon is not necessarily in the interests of the DCA and Department of Defense on the following grounds:

(i) The DCA would probably not share the cost benefits of such actions; they would not result in reduced charges to the DoD.

(ii) An uncontrolled transition could make it impossible to exploit the full potential of technological developments.

c. Developments in Commercial Domestic Satellite Technology. The history of the INternational TELecommunications SATellite Organization (Intelsat) beginning with the Communications Satellite Act of 1962 is well known. For CONUS AUTOVON, however, the relevant developments

TABLE III-1. SUMMARY OF BENEFITS OF THE BASCOP ARCHITECTURE

Lower First Cost	Lower Recurring Cost	Improved Grade of Service	Compatibility and Flexibility
Integrated transmission and switching requires less equipment.	High equipment reliability with extensive self-testing.	Full availability matrix architecture.	Compatible with the Switched Digital Network, the master plan for the evolution of the DDD network.
Full availability, non-blocking digital matrix requires fewer trunks for equivalent ccs traffic capacity.	Reduced maintenance costs since no relays are used in call switching.	Rapid call processing.	Full stored program control of call processing functions makes feature additions simple to implement.
T-carrier proves-in at zero or short distance on T1 terminations.	Through-balance and terminal-balance are easily maintained due to 4-wire switching.	Improved transmission quality.	Distributed switching capability provides the network planner with a new range of alternatives.
Short installation and cutover intervals are possible due to extensive connectorization and factory system test.	Lower training and operating costs result from simplified dial administration and traffic engineering: no graded multiples, no junctor grouping, routing changes entered through keyboard.	Real time traffic reports aid identification of defective trunks.	Inherent capability for baseband data interface.
Building space conservation or space recovery can defer or eliminate building additions.	Office traffic balance is not critical due to high traffic capacity.		

began in 1972 when the Federal Communications Commission authorized the United States common carriers to construct and operate satellite systems for domestic telecommunications in the "free enterprise" mode as opposed to the regulatory mode. The AT&T Company was prohibited from furnishing new private line services via satellite prior to 1979, although this prohibition does not extend to services for the U.S. Government. Thus, the DCA has an opportunity to deal with any of the satellite-oriented carriers in a competitive environment.

The DCA began direct leasing (as opposed to indirect leasing of circuits via the common carriers) from the satellite carriers in 1977 when a 1.544 Mb/s service between Hawaii and California was leased directly from Western Union. The government provided the multiplexing and bulk encryption for AUTOVON service. Since then, two 1.544 Mb/s circuits were leased from AT&T Domestic Satellite and Telesat of Canada for linking a northern Canadian location to Ft. Leavenworth, Kansas.

However, further developments in domestic satellite systems offer even greater opportunities for DCS Services in the future.

(1) Domestic Satellite Systems As Of 1978. At present, the capabilities of all the domestic satellites are basically the same from the standpoint of applicability to AUTOVON. Those include the space systems of AT&T/GTE, RCA, and Western Union. American Satellite Corporation has its own earth stations but leases transponders on the Western Union Satellites. They all operate in the 4-6 GHz range, although the frequency assignments of the transponders are not identical.

The current AT&T earth stations are all large because they are primarily intended for long haul trunking. The satellite links are just another type of transmission media to be used in the overall AT&T long haul plant. Use of the satellite is generally on a single carrier per transponder basis. The RCA and Western Union earth stations are generally smaller and intended for private line services and special applications. A problem with using small earth stations (e.g., a 5 meter diameter dish) on customers premises in the 4-6 GHz band is that of interference. The orbital congestion (limited arc separation of satellites) and many terrestrial microwave systems mitigate against widespread utilization of small earth stations at data rates above several hundred kilobits per second.

(2) Domestic Satellite Systems In The 1980's. AT&T Long Lines is currently planning its next generation system to replace Comstar in the late 1980's. It is expected to carry 4 and 6 GHz, 12 and 14 GHz, and possibly 20 and 30 GHz transponders to provide high capacity trunks between major cities as well as to serve the private line market (assuming the FCC prohibition against AT&T is lifted).

In January 1977, Western Union contracted with NASA to provide tracking and data relay satellite systems (TDRSS) for all of NASA's earth orbiting satellites including the Shuttle. This service will replace NASA's worldwide network of ground stations. It will simultaneously provide Advanced Westar service in the 4 and 6 GHz and the 12 and 14 GHz bands to Western Union's commercial customers. The TDRSS/Westar Satellites will be launched by NASA's Shuttle on the first operational flight in the early 1980's.

The Advanced Westar system will employ a large number of relatively small earth terminals so that an individual private line subscriber (such as AUTOVON) could can have its own dedicated satellite communications link for high speed data and voice traffic [8]. The details of the communications services to be offered are not yet firm. Some of the major capabilities of Advanced Westar include:

- Data from 75 b/s to 250 Mb/s; digital/analog voice (including secure voice); high-speed facsimile; video conferencing at 6.5 Mb/s; broadcast-quality video.

- 12 C-band transponders per satellite, and a K-band capacity totaling 1,000 Mb/s with satellite switching and movable beams.

- Private networks accessible from rooftop or parking-lot antennas.

- 1.544 Mb/s interface at ground station.

Satellite Business Systems (SBS) is planning to launch a new series of domestic private line satellites in the 12 and 14 GHz band in the early 1980's. SBS intends to install private communications networks for some of the Fortune 500 leading corporations and large public institutions throughout the contiguous United States.

This particular system is different from most of the satellite carriers in that SBS is planning to market what amounts to total integrated voice, data, and image services [9]. Of significance to the DCA is that only contiguous U.S. coverage will be provided. The service is not intended to extend to Hawaii and Alaska. Also, SBS intends to offer a proprietary privacy system which thus makes possible a service that enjoys system privacy.

Of special interest to DCA (in comparison to the offerings of the other major satellite carriers) is the SBS Satellite Communications Controller (SCC). The SCC functions as a time division switch, information processor, and controller. It is an integrated hardware and software device which itself includes a small data processor. The SCC performs

the following principal functions:

- Analog/digital voice conversion (delta modulation)
- Data signal forward error correction coding/decoding
- Voice activity compression (VAC)
- Signaling
- Call processing
- Circuit switching
- Echo suppression
- Formatting, framing, synchronizing
- Multiplexing
- Multiple access control
- Demand assignment (DA) control.

The power of the SCC allows SBS to make the claim that the user of their network facilities will be provided an assortment of advanced features including:

- Flexible voice and data conference arrangements
- Multipoint distribution of digital data, which can include document distribution (electronic mail service)
- Teleconferencing including multipoint video conferences
- Network access control features.

d. Implications To AUTOVON. The commercial telecommunications environment in the 1982-1992 period is visualized as a continued evolution to digital systems with inherent economic and performance advantages. In order for DCA to take advantage of this environment, new concepts for implementation of the CONUS AUTOVON must be explored and new tariff structures identified and pursued with the commercial carriers. In contrast to today's tariffs which are based on investment, tomorrow's tariffs might be based on maintenance alone. The new technology will be software intensive (one-time effort) while equipment and maintenance costs

will be greatly reduced below today's.

The terrestrial transmission and switching technological developments discussed in the above paragraphs motivate the following AUTOVON considerations:

- Examination of preferred switch locations and transmission media in a new digital dedicated network.
- Exploration of a virtual AUTOVON embedded in the DDD network and controlled by standard software and traveling classmarks.
- Re-examination of AUTOVON service features in light of digital switch capabilities.
- Exploitation of off-the-shelf commercial hardware, software, and firmware available in the 1980's.
- Investigation of new cost sharing arrangements based on utilization of shared communications resources.
- Exploitation of digital switching and transmission on posts, camps, and stations.

Two limitations which will influence satellite communications in the future are spectrum allocation and orbital congestion [3]. The technologies required to minimize the impact of these constraints are:

- Multiple beam antennas.
- On-board switching and processing.
- Economical launch vehicle capability.
- Inter-satellite communications links.
- Exploitation of higher frequencies.
- Demand assignment.

Most of these technologies are evident in the next generation of satellites planned by the satellite carriers, as indicated in the previous paragraph. The overall trend is toward expanded services that are met by larger and more capable spacecraft. The net result is that smaller and relatively simple satellite earth terminals can operate with complex satellites, hence providing an overall cost savings and improvement in

performance for the customer of the system.

The potential of small satellite earth terminals on the customer's premises, with options to go terrestrial via the local digital switches, has interesting implications to AUTOVON. First of all, it provides another medium for survivability enhancement. Secondly, the long haul subscriber-to-subscriber traffic could be transmitted and switched (demand assigned) at a potentially significant cost reduction from present methods by reducing terrestrial access and backbone transmission requirements. These aspects will be considered for application to the next generation CONUS AUTOVON.

8. DCS III CONCEPTS

The architectural alternatives for the future DCS III have been described [10], and are differentiated by the interaction between switching and transmission, and the mix of satellite and terrestrial media. The alternatives include:

- A two-level hierachical switching approach wherein satellite access is achieved from the highest level with terrestrial transmission provided for second level connectivity.

- A single-level backbone switching approach that removes the hierachical switching mode structure, simplifies the backbone nodal terrestrial connectivity, and allows satellite access from the restructured backbone nodes.

- A local switching node approach that further refines the backbone node and connectivity restructure and allows satellite access from local, or on-base, nodes.

Each architectural alternative is defined by its switching, transmission, and control subsystem concepts. The switching concepts include circuit, packet, and hybrid approaches. Satellite and terrestrial media describe the transmission and topological concepts. The control concepts include highly centralized, fully distributed, and modified hierarchical.

The overall direction of the DCS III is towards all-digital operation, increased utilization of satellite systems, and unified switching of voice and nonvoice traffic. The next generation CONUS AUTOVON, as a subsystem of the DCS, should therefore not be precluded from moving in the direction currently envisioned for the DCS III.

The available communications resources and services in the 1982-1992 time frame primarily will be those discussed in paragraph 1 of this

section. Whether or not these resources are leased or purchased is the subject of a more refined analysis that may have to be considered at a later time. Needless to say, the commercial AT&T network, consisting of local offices and tandem switches (the digital trend is evident), is an example of the two-level hierarchical switching alternative proposed for the DCS III. Similarly, digitizing the current AUTOVON and supplementing terrestrial with satellite transmission is representative of the single-level architectural alternative for the DCS III. The third candidate for DCS III architecture reflects the trend in services offered by the satellite carriers (i.e., provide services with satellite ground terminals at the subscriber location) and the increasing utilization of digital switches on bases and large government complexes.

As is evident, the telecommunications resources in the interim (between now and the post-1992 period) are in fact leading towards the range of alternatives under consideration for the DCS III. Whether or not the final DCS III solution is one of the candidate architectures or a mix of the preferred attributes of each, it is unlikely that the ongoing study on The Next Generation CONUS AUTOVON will preclude any of these possibilities. Indeed, it is more likely that the study presented in this report will provide insight to the analysis and ultimate determination of the DCS III preferred architecture.

IV. NEXT GENERATION CONUS AUTOVON ALTERNATIVES

1. INTRODUCTION

This section describes the requirements, design goals, and three major courses of action open to DCA in planning for the next generation CONUS AUTOVON. Six alternatives, based on these courses of action, have been developed to provide a convenient means of exploring alternative concepts. The alternatives were developed by consensus at DCEC, staffed through the DCA Headquarters, and were approved by The Director, DCA in February 1978. CONUS AUTOVON is a tariffed offering by American commercial carriers within the contiguous United States. The analysis of CONUS AUTOVON described in this report is also based on leased facilities or services in contrast to government-owned systems.

2. CONUS AUTOVON REQUIREMENTS

The requirements for the next generation CONUS AUTOVON are divided into the categories of operational/capabilities requirements and traffic load requirements. The first category refers to the collective set of requirements a potential user of the system would impose as a reflection of the specific operational needs of his mission. This collection of user-oriented requirements then poses specific performance capabilities that CONUS AUTOVON must provide. The second category of requirements reflects the subscriber from-to traffic (measured in Erlangs) that must be carried by the network with a specified grade of service (GOS) derived from operational requirements.

The two categories of requirements are considered further in paragraphs 2a and 2b and are followed in paragraph 2c with a brief discussion on the CONUS environment within which the next generation CONUS AUTOVON must operate.

a. Operational Requirements/Features. Preliminary identification of the operational requirements/features of next generation CONUS AUTOVON subscribers has been made based upon:

- Knowledge of current CONUS AUTOVON subscribers requirements and their anticipated future needs.
- Future secure voice requirements.
- Selected Special Purpose Network (SPN) subscriber requirements.
- The requirements of AUTODIN subscribers that are candidates for using AUTOVON for transmission of selected categories of data (e.g., Narrative/Record and bulk data transfers).

The resulting operational requirements are listed in the left hand column of Table IV-1. The candidate subscriber categories are listed at the top of the table and the table entries relate the requirements to the subscribers. The entry is quantitative where possible (e.g., connection time) and qualitative elsewhere to indicate the level or degree to which the requirement must be satisfied for the specific candidate subscriber. The table entries can be interpreted as performance and capabilities objectives for the next generation AUTOVON.

The list of candidate subscribers is self-explanatory except, possibly, for the Special Purpose Network (SPN) user who currently uses nonswitched dedicated circuits. A tentative list of these SPN subscribers and the rationale for this selection are presented in Table A-V of Appendix A. This category of subscriber is considered to provide a system capability that will satisfy his unique requirements and thereby give him the opportunity to avail himself of the service if economically advantageous. The tentative list of SPN subscribers involves approximately 805 dedicated circuits of which 92% are less than 500 miles (805 km) in length (these circuits are intra-CONUS only). Many of the SPN users are collocated with existing CONUS AUTOVON subscribers. By including the locations that are not collocated, the number of AUTOVON subscriber locations increases by about 15% (resulting in a total of 839 subscriber locations).

With reference to Table IV-I, note that the SPN, secure voice, special purpose AUTOVON, and selected AUTODIN subscribers have operational requirements that are significantly more difficult to satisfy than the administrative AUTOVON subscriber. For this reason, it is convenient to divide the subscribers into two groups so that specific consideration can be directed to each in the ensuing analysis of AUTOVON alternatives. The first group encompasses the bulk of the day-to-day administrative users who currently use AUTOVON. The second group includes all those with unique operational requirements (i.e., SPN, secure voice, special purpose AUTOVON, and selected AUTODIN subscribers). These two groups are accordingly called administrative subscribers and operational subscribers respectively. The traffic levels generated by these two subscriber groups are discussed in the following subsection.

b. Traffic Requirements. The development of the from-to subscriber traffic matrix is explained in Appendix A for each of the two groups of subscribers: namely, the administrative traffic and the operational traffic. The total traffic load that must be carried by any future CONUS AUTOVON is approximately 5000 Erlangs of administrative traffic and 600 Erlangs of operational traffic.

TABLE IV-I. SYSTEM PERFORMANCE AND CAPABILITIES OBJECTIVES FOR CONUS AUTOVON

OPERATIONAL REQUIREMENTS \ CANDIDATE SUBSCRIBERS	CLEAR VOICE AUTOVON USERS: SPECIAL PURPOSE	CLEAR VOICE AUTOVON USERS: ADMIN	SECURE VOICE SUBSCRIBERS	SPECIAL PURPOSE NETWORK USERS (DEDICATED)	SELECTED AUTODIN TRAFFIC (RECORD AND BULK)
Voice Quality:					
• Intelligibility	high	Par with present standards of the U.S. Public Tele. Serv.	high	high	NA
• Recognition	-		yes	-	NA
• Naturalness	-		yes	-	NA
• Noise/echo/delay	low		low	low	NA
• A/D Tandeming Capability	good		good	-	NA
Security:					
• End-to-end encryption	-	-	yes	some	yes
• Bulk encryption	desirable	desirable	-	desirable	-
• CCS Channel encryption	desirable	desirable	desirable	desirable	-
Connectivity:					
• Connection time	2-3 sec.	<10 sec.	<10 sec.	2-3 sec.	<4 sec.
• Accessibility & assurance for continuity of service	GOS Vs Precedence	GOS	GOS Vs Precedence	GOS Vs Precedence	GOS Vs Precedence
• Variable precedence capability dependent upon threat/crisis	yes	no	yes	yes	yes
• Interoperability with overseas AUTOVON	yes	yes	yes	yes	-
• Improved capability for circuit restoral via AUTOVON	-	-	-	yes	yes
• Emergency trunking	yes	no	yes	yes	yes
Survivability:					
• Jamming vulnerability	low	-	low	low	low
• Intercept	low	low	-	low	-
• Network survivability	high	good	high	high	high

(continued)

TABLE IV-I. SYSTEM PERFORMANCE AND CAPABILITIES OBJECTIVES FOR CONUS AUTOVON (Continued)

CANDIDATE SUBSCRIBERS / OPERATIONAL REQUIREMENTS	CLEAR VOICE AUTOVON USERS		SECURE VOICE SUBSCRIBERS	SPECIAL PURPOSE NETWORK USERS (DEDICATED)	SELECTED AUTODIN TRAFFIC (RECORD AND BULK)
	SPECIAL PURPOSE	ADMIN			
Conferencing:					
• Preset voice conferences	yes	-	yes	yes	-
• Add-on conferencing	yes	-	yes	yes	-
• FAX conferencing	yes	-	-	yes	-
• Video conferencing	perhaps	no	no	perhaps	-
Service Features:					
• Abbreviated dialing	yes	yes	yes	yes	-
• Zone restrictions	no	yes	yes	no	no
• Automatic notifications of excessive holding time	no	no	no	yes	-
• Call forwarding	yes	yes	yes	yes	-
• Camp-on	desirable	desirable	desirable	desirable	-
• All call alerting	yes	no	yes	yes	-
• Community of interest calling	yes	no	yes	yes	-
• off-hook service	yes	no	yes	yes	-
• Automatic call transfer	yes	desirable	yes	yes	-
Special Features:					
• Full duplex facsimile	yes	no	no	yes	-
• Broadcast facsimile	yes	no	no	yes	-
• Automatic interconnect of official AUTOVON overflow calls to commercial network	yes	no	no	yes	no
• Mobile/air interface	yes	no	yes	yes	no
• Telephone Recording	yes	no	no	yes	no
• Multi-rate data	yes	no	yes	yes	yes

The percentage of traffic destined for locations farther than 1200 miles (1,930 km) is approximately 25%. The majority of this traffic is coast-to-coast. About 50% of the traffic is destined for locations farther than 600 miles (966 km). A histogram depicting these results is presented in Appendix A (Figure A-2). Also, Figure A-3 indicates large masses of traffic density along the eastern, southern, and western coastlines of the CONUS with Washington, D.C., San Diego, Los Angeles, Norfolk, Philadelphia, St. Louis, and Boston representing pockets of dense traffic.

The combination of the two traffic matrices represent the total traffic load to be carried by a future CONUS AUTOVON system (either a single network or a combination of networks) with a specified grade of service determined by the operational requirements. The determination of whether or not to satisfy the traffic load with a single network (assuming it can meet the most stringent operational requirements) or with separate networks oriented toward separately satisfying unique operational requirements (primarily survivability considerations) is considered in this report. The alternatives described later in this section will reflect these considerations.

c. The CONUS Environment. The next generation CONUS AUTOVON will be designed and implemented in a changing regulatory, political and technical environment. The regulatory and political issues are beyond the scope of this study and, in fact, transcend the jurisdiction of DCA. At most, the planning and engineering of future systems for the 1980's can provide the flexibility to adjust for changes introduced by regulatory decisions and unforeseen technologies.

The major technological developments that will impact the next generation CONUS AUTOVON are discussed in section III. The trend toward digital communications systems will generate new kinds of services, which result in new tariff structures, and may influence current tariffs through reduced operating costs.

Digital technology is now at the point where, if properly applied, it can bring about a new kind of switched network in which the distinction between switching and transmission is diffused and a synergy is created which provides new benefits over and above those which each system element (e.g., a T-carrier trunk or local switch) enjoys. Some of these benefits might be a uniform grade of service (regardless of distance), vastly improved maintenance due to automation (easier with digital than analog), and much lower end-to-end cost due to the near-elimination of analog-digital (A/D) interfaces [11].

One of the most important changes in an all-digital system is that of signaling and voice processing. The A/D, dialing, ringing, and

switchhook equipments are being eliminated and the corresponding functions taken over by integrated logic, including small economical microprocessors. In an all-digital environment, with digital switching and compatible digital transmission, the technical control facilities also disappear. In fact, the similarity to today's switching center, access line, and terminal instrument is not too obvious and the difference between station equipment served by a PBX and by a larger central office begins to fade.

Economic considerations, however, must be bounded by the requirements of a viable technical plan. The roadblocks in planning a digital AUTOVON in an evolving CONUS intertoll network which is now analog and which may remain substantially analog for many years in the future are fully appreciated. The telecommunication planners cannot generally agree on how far in the future is the all digital world.

Nevertheless, this study is based on the idea that the CONUS transition to digital switching is underway and that the all-digital integrated DCS III is a reasonable goal. One alternative in the study looks at retaining the analog switches for comparison purposes only and to indicate what a modest upgrade might provide.

3. SYSTEM DESIGN GOALS AND PERFORMANCE OBJECTIVES

a. Goals of the CONUS AUTOVON System Design. The intent of this study of the next generation CONUS AUTOVON is to identify and explore the system attributes that effectively and economically provide the necessary capabilities to satisfy the requirements in the changing CONUS environment of the 1982-1992 time period. These attributes will form the technical basis for continued planning and system design efforts associated with evolving to a future CONUS AUTOVON.

The major system design goals include the following:

- Provide a system with greater economy of operations.
  - system flexibility to take advantage of new services and tariffs.
  - reduction/elimination of manpower intensive equipments and operations (assuming manpower is expensive or scarce).
  - utilization of commercially available systems/components/software, where possible.

- Provide improved system performance characteristics.
  - system capabilities and survivability enhancements to offer the potential for including the SPN subscribers in the next generation CONUS AUTOVON.
  - capability to handle multi-rate digital voice/data.
  - interoperability with non-CONUS AUTOVON (i.e., Canada, Alaska, Caribbean, and overseas).
  - secure communications and privacy capabilities.
- Provide greater operational efficiency.
  - flexibility to adapt to changing traffic patterns and inclusion of new subscribers.
  - Automatic functions and procedures via software where practical.
  - exploitation of new service features to enhance operational effectiveness.
  - a capability for rapid extension, augmentation, and restoration.

These system design goals and the system performance objectives (discussed in the next paragraph), in concert with the requirements, form the technical basis for defining alternatives and exploring potential system attributes.

b. CONUS AUTOVON Performance Objectives. The identified operational requirements and estimated traffic loads provide the basis for establishing preliminary system performance objectives. The translation of requirements into detailed performance objectives is a complex undertaking which goes beyond the level of engineering intended in this study. However, for purposes of evaluating conceptual alternatives, it is sufficient to establish broad system performance/capability objectives.

Table IV-I lists the operational requirements of the candidate subscribers and, in many cases these can be translated into broad system performance/capability objectives on a one-to-one basis. Therefore, the contents of Table IV-I are interpreted as system performance/capability objectives for purposes of this study. It should be noted that for the two groups of users defined (administrative and operational) the requirements and resulting system objectives are quite different for each. This fact necessitates special system considerations for each type of user and leads to system alternatives constructed specifically to accomodate this situation.

The significant performance/capability objectives for purposes of conducting the CONUS AUTOVON study are as follows:

- The backbone GOS is P.13, which is in consonance with current operational practice.

- Generally, the performance and capability to handle administrative traffic should meet telephone company standards.

- The system must support operational subscribers that require connection times on the order of 2 to 3 seconds, and should provide a capability to guarantee network accessibility and assurance for continuity of service.

- The system should support reliable secure communications traffic (voice and record) and provide conferencing capabilities (essential for operational subscribers).

- The system should provide a useful communications capability throughout the spectrum of defense functions (i.e., deterence in peace, crisis, and war) for the operational subscribers.

4. APPROACHES TO PLANNING AND ENGINEERING THE CONUS AUTOVON

The planning and engineering efforts for the next generation CONUS AUTOVON will be heavily influenced by the technological developments and regulatory environment in the 1980's. This should be evident from material presented in the report up to this point. Additionally, subscribers are becoming more sophisticated and state their requirements in terms of mission related technological capabilities which are also advancing at a rapid pace. This, in turn, places new demands on communications systems.

Based on the broadly described dynamic environment, it appears there are three major courses of action open that can lead to the next generation CONUS AUTOVON. This does not preclude the possibility of some combination of the approaches being considered. However, for purposes of this study it is convenient to examine a limited number of sufficiently different approaches to determine the advantages and disadvantages of each. The three major courses of action open for consideration in CONUS are:

- Continue with the present concept (lease a dedicated AUTOVON from the AT&T and the Independent Companies).

- Follow the telephone industry service offerings (take advantage of their plans and developments as introduced to the public at large).

- Create a new CONUS AUTOVON based on new technology.

The first course of action allows for selected upgrades, reconfiguration of the current network, and replacement of analog switches with digital switches. The system would handle both the administrative and operational subscribers in one dedicated network as it does today. For purposes of analysis and comparison with other approaches, two alternatives are defined within this course of action. The first involves minimum upgrade (add common channel signaling (CCS) to the present network) and the second deals with digital switching. These alternatives are discussed in detail later in this section.

The second course of action permits exploitation of new telephone company services and capabilities which are rapidly evolving via digital communications techniques. DCEC concensus suggests that performance objectives for operational subscribers can not be met by normal CONUS commercial services and that a small dedicated network is required to augment the commercial network to satisfy these deficiencies. (Primary concern addresses continuity of service during contingencies, survivability, and access to the Overseas AUTOVON.) Two alternatives are also defined for this approach and involve the use of No. 4 ESS switches and the WATS service.

The final course of action allows for exploitation of new technological developments. In particular, examination of how best to use digital switches and small satellite terminals to satisfy the requirements is a primary motivating factor. Additionally, it leads towards the conceptual configuration and capabilities of DCS III. Two alternatives were also identified for this course of action. The first involves a distributed private line switched network with many small digital switches and some long-haul point-to-point satellite transmission. The second alternative exploits small satellite terminals in the access area and shares the satellite resource via demand assignment techniques. Both the administrative and operational subscribers can be satisfied by the distributed private line network as is the case today. Because of the possibility of satellite jamming (or failure) in the second alternative, a small terrestrial network further augments the basic satellite network in order to provide the additional worldwide capabilities required for the operational subscribers and to accommodate short-haul traffic for both.

5. DESCRIPTION OF ALTERNATIVES UNDER STUDY

Table IV-II summarizes the characteristics of the six alternatives selected for study. The alternatives were based on those factors of the FCC tariffs that determine the costs for service. Today, for example,

TABLE IV-II. DEFINITION OF CONUS AUTOVON ALTERNATIVES

COURSES OF ACTION	NEXT GENERATION CONUS AUTOVON				MACROSCOPIC ATTRIBUTES									
		MOTIVATION			DEDICATED TRUNKING							NON-DEDICATED TRUNKING		
	DESCRIPTION	COST REDUCTION	NEW TECHNOLOGY & NEW SERVICES	ALT NO.	TERR. NET		SWITCH TYPES		SWITCH LOCATION		PT-PT	PRIVATE LINES SERVICES	WATS	SATELLITE SERVICES (DAMA)
					LG.	SM.	ANA.	DIG.	EXIST.	SUB. LOC.	SATELLITE TRUNKING			
CONTINUE PRESENT APPROACH	MINIMUM UPGRADE	NONE	COMMON CHANNEL SIGNALING	1	X		X		X		X			
	REPLACE SWITCHES	REDUCE SWITCH INVEST.	DIGITAL SWITCHING	2	X			X	X		X			
FOLLOW TELCO DEVELOP-MENTS	COMM'L SERVICES PLUS DEDICATED NETWORK	REDUCE SWITCH. & X-MISSION	TELCO UP-GRADE: NO. 4 ESS	3		X		X	X		X	X		
		MINIMIZE NO. OF SWITCHES	TELCO UP-GRADE: WATS	4		X		X	X		X		X	
NEW ADVANCED CONCEPTS	DISTRIBUTED TERR. NETWORK	REDUCE ACCESS X-MISSION	ON-BASE DIGITAL COMM.	5	X			X		X	X			
	DISTRIB. TERR. NET WITH SAT. IN ACCESS AREAS		NEW SAT. SYSTEM CAPABILITIES W/SM. EARTH TERMS.	6		X		X		X				X

switching center charges are based on the SCAN tariffs, and TELPAK and other transmission tariffs determine the access line and interswitch trunking charges. For purposes of the study it was convenient to examine a limited number of sufficiently different approaches to determine the advantages and disadvantages of each concept. The goal of the analysis was not the selection of an alternative but the identification of available options and decision points. The alternatives thus represent options within the planning cycle of 1982-1992. In order to simplify the computation process, 1985 was chosen as the technology design and cost base year. SCAN charges were increased appropriately and MPL costs were substituted for TELPAK.

In addition to the six alternatives presented, a Baseline Alternative, sometimes referred to in the study as Alternative 0, was used. Alternative 0 is the CONUS AUTOVON as it will be configured with the 45 switching centers remaining in October 1979. The costs for this network were also extrapolated to 1985. This was the true "do nothing" approach and was used for comparison purposes only.

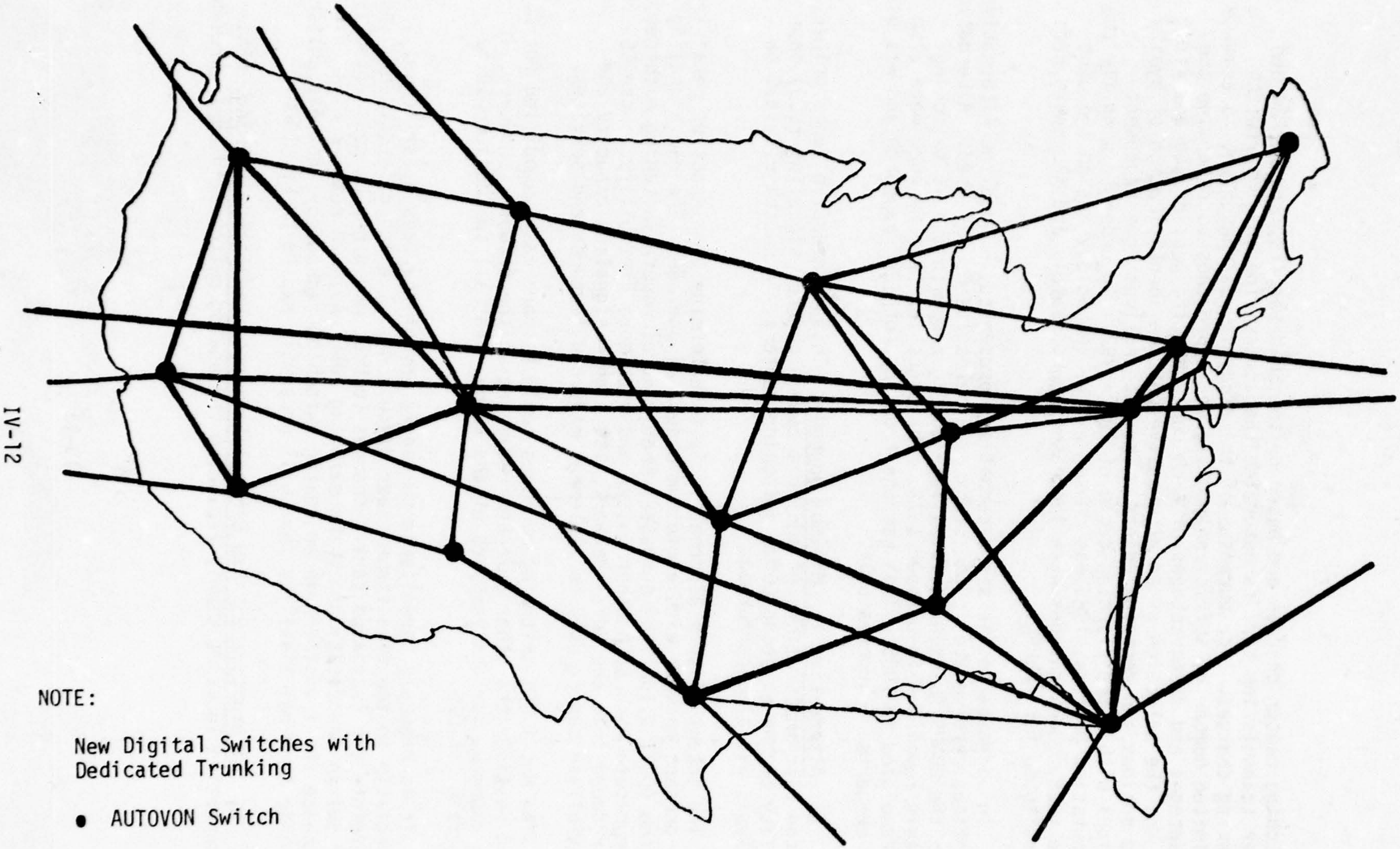
a. Alternative 1: Minimum Upgrade. This alternative looks primarily at the cost implications of adding a common channel signaling (CCS) capability to the existing CONUS switching centers. A switch elimination analysis was also performed.

The intent of this alternative is to determine the impact of retaining the present network with a minimum essential upgrade. The new signaling system (CCS) allows the computers that control modern switching machines to communicate with each other faster and with more flexibility. Once CCS is introduced into the total network, its higher signaling capacity and flexibility can be used to implement many new features and services.

The No. 1 ESS switching machines could be more easily modified for CCS than possibly the other switches remaining in the network. However, it was assumed, for the purposes of the study, that all switches would be modified for CCS.

It is probably unrealistic to modify any of the present switches, especially in the time frame under discussion. The added investment, and therefore the increased tariff charges to DoD, would not be cost effective. Any switch modifications to the existing CONUS AUTOVON network will only increase the investment in an analog switching technology and reestablish a basic terminal liability that will presently expire on May 1980.

b. Alternative 2: New Digital Switches, Dedicated Trunking. This alternative looks at simply replacing the analog switches in their present



NOTE:

New Digital Switches with Dedicated Trunking

● AUTOVON Switch

Figure IV-1. Alternative 2

locations with digital switches controlled by a stored program common control (see Figure IV-1). The primary intent is to determine the impact of replacing the large investment in the current AUTOVON space division analog switching machines with the lower cost digital switches. Digital switching technology can already produce these specific advantages: occupying smaller floor space; cheaper switching matrices; and cheaper tandem switching, especially if pulse code modulation (PCM) systems can be directly terminated on the machine [12]; and lower cost maintenance.

Furthermore, digital switches can be modularly adjusted to changes in subscriber requirements. The size of today's analog switches were fairly well fixed at the time of installation and today's CONUS AUTOVON switches are only about 40% utilized.

The projected growth in CONUS AUTOVON communications requirements has never materialized, and the switch sizing is not easily adjusted. One option open to the Government has been switch closures.

c. Alternative 3: New Digital Switches Homed on No. 4 ESS. Approximately 60% of the backbone charges are transmission costs. This alternative looks at a method whereby those interswitch trunking costs might be reduced.

Alternative 3 uses new digital switches constrained to existing AUTOVON locations. Trunking is on a dedicated basis among only those switching centers that support operational traffic. The study identified 10 sites throughout CONUS to support these operational services. A total of 26 digital AUTOVON switches are required to serve the combined operational and administrative traffic. All switches are homed to the commercial DDD through the nearest No. 4 ESS. The No. 4 ESS forms a portion of a stored program control network of tandem switching centers. They, too, are interconnected by CCS. Administrative traffic is routed from the originating AUTOVON switch to the terminating AUTOVON switch through the DDD toll network via the No. 4 ESS. It is anticipated that there will be approximately 140 No. 4 ESS's in the Bell System and the Independent companies by 1985.

Actually, the No. 4 ESS's are all programmed to be installed in the centers of large metropolitan areas. This has had an adverse impact on the survivability analysis of this alternative. (See Appendix D for details). Furthermore, accessing the No. 4 ESS from each CONUS AUTOVON switch has resulted in some backhaul trunking in the modeling exercise, which has inserted some additional costs for the trunking and the CCS channel. In actual implementation, the AUTOVON switch might be homed to the nearest toll switching center equipped for CCS.

Two methods of utilizing the DDD were investigated in this alternative. One concept involves establishing all connections through the

toll network on a per-call basis. The No. 4 ESS would act like an automatic patching facility, setting up and taking down calls from AUTOVON. AUTOVON would be billed only for the time to complete each call. The other concept involves some minimum number of "nailed up" connections through the No. 4 ESS and the toll network to another AUTOVON switch. The commercial network of the No. 4 ESS's would actually provide full-period interswitch trunks for AUTOVON. Under either concept, a special "traveling class mark" over the CCS channel would indicate to all switches in the routing path that an AUTOVON call is in transit that it should be afforded special routing consideration during contingencies.

It was recognized that the commercial network does not offer MLPP. But, in this case, the commercial network can be thought of strictly as providing trunking between AUTOVON switches. The new digital AUTOVON switches would permit preemption from either end of the call.

MLPP would be provided, however, over the dedicated network for the operational traffic. This network also provides access to the overseas AUTOVON. Figure IV-2 depicts Alernative 3.

Unfortunately, the per-call concept through the toll network could not be modeled or evaluated. Too many unknowns or uncertainties for the 1985 toll rates precluded an analysis. The alternative was priced out for the administrative network using the "nailed-up" concept. Even this represents a pessimistic cost estimate over a time shared concept.

While both of these concepts are technically feasible, there is also no assurance that such an offering would be submitted by the industry. Also, there are variations to these concepts that may merit a more detailed study.

c. Alternative 4: "Virtual AUTOVON" on DDD, or WATS. In Alternative 4, AUTOVON retains the concept of a small dedicated network to serve DoD high priority users, as in the previous alternative, and consists of the switching and transmission necessary to satisfy AUTOVON operational requirements and interoperate with the overseas AUTOVON.

But, in this alternative, the amount of dedicated trunking investment is further reduced by diverting the bulk of the traffic to a "virtual" AUTOVON embedded in the commercial DDD. The administrative subscribers would be served by a WATS service and not through AUTOVON switches of any type. MLPP will be exercised only throughout the dedicated network. Figure IV-3 depicts Alternative 4 in the DCEC study.

A "WATS-type" service was considered for this alternative in the early part of the study, where the calling subscriber would be limited to

WITH NEW DIGITAL SWITCHES HOMED ON #4ESS

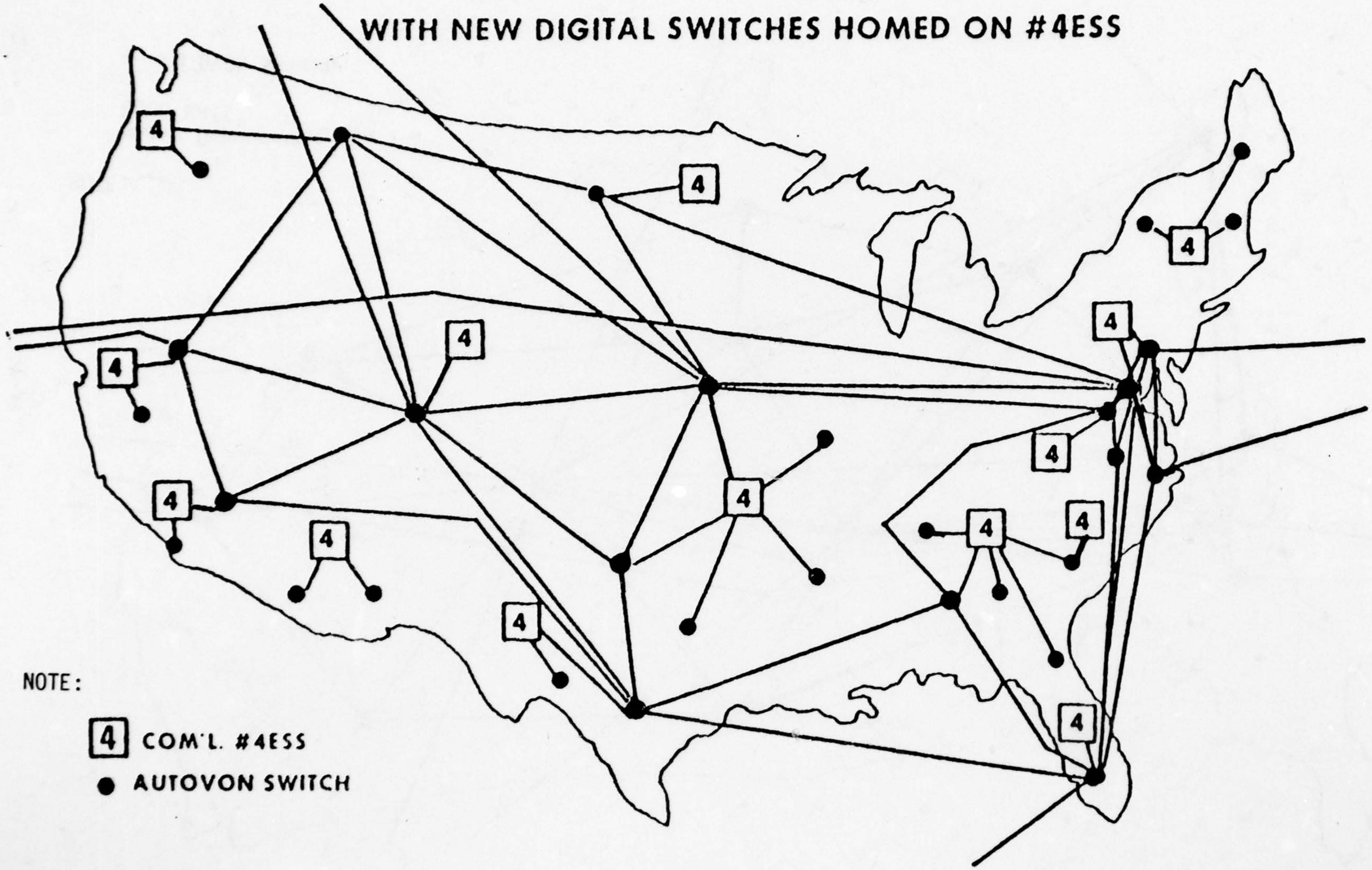


Figure IV-2. Alternative 3

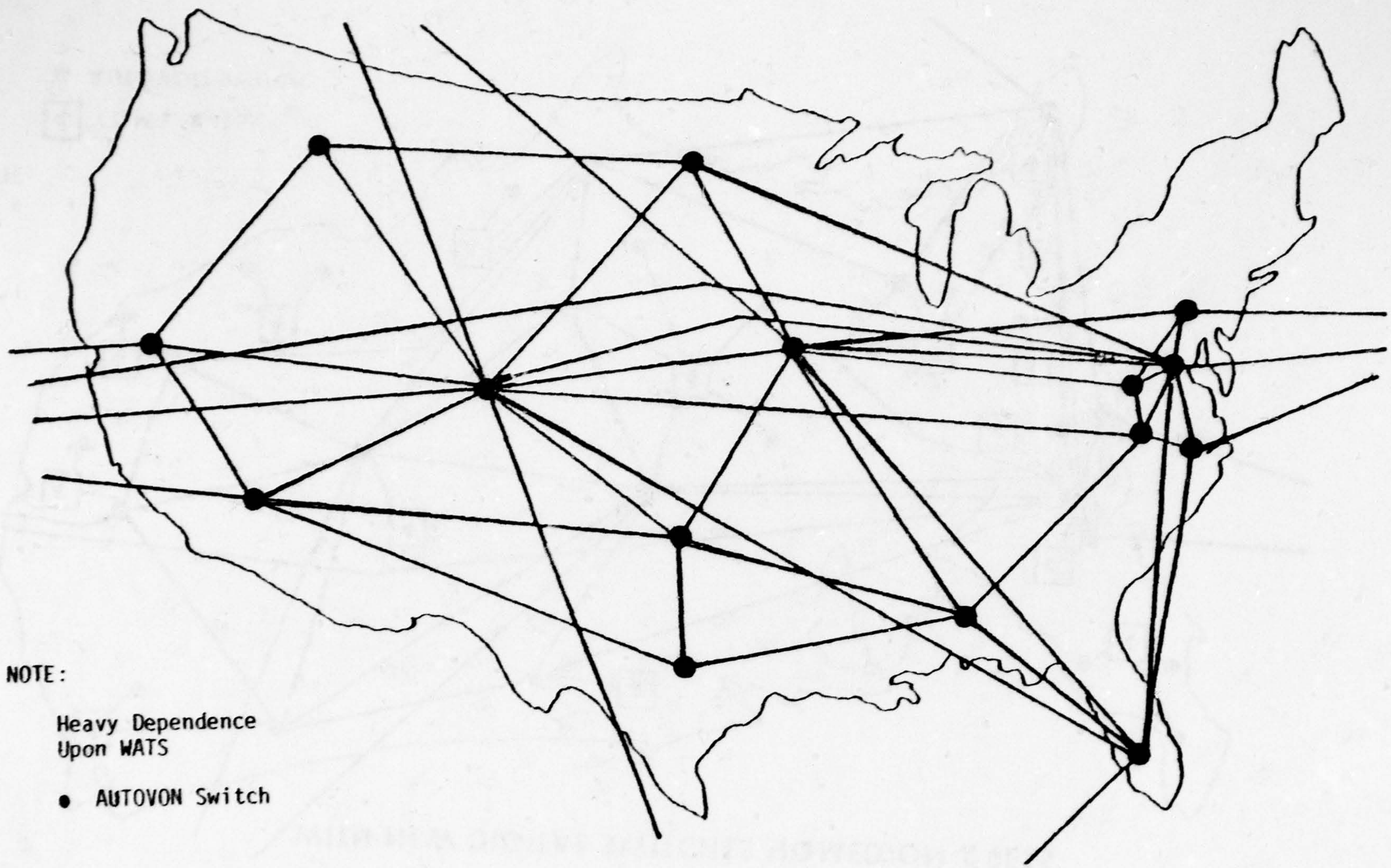


Figure IV-3. Alternative 4

calling other AUTOVON subscribers throughout the CONUS. Investigation quickly pointed out that this very limitation would impose more software problems (and therefore increased costs to the AUTOVON) than the fully unrestricted or general WATS services.

Only a very general analysis of this alternative was made during the course of this study. An accurate study would take a thorough communications analysis of each military post, camp, and station in the CONUS. Their calling patterns, destinations, time of day, duration of call, etc., would also have to be considered along with any existing calls over WATS and/or via long distance (LD).

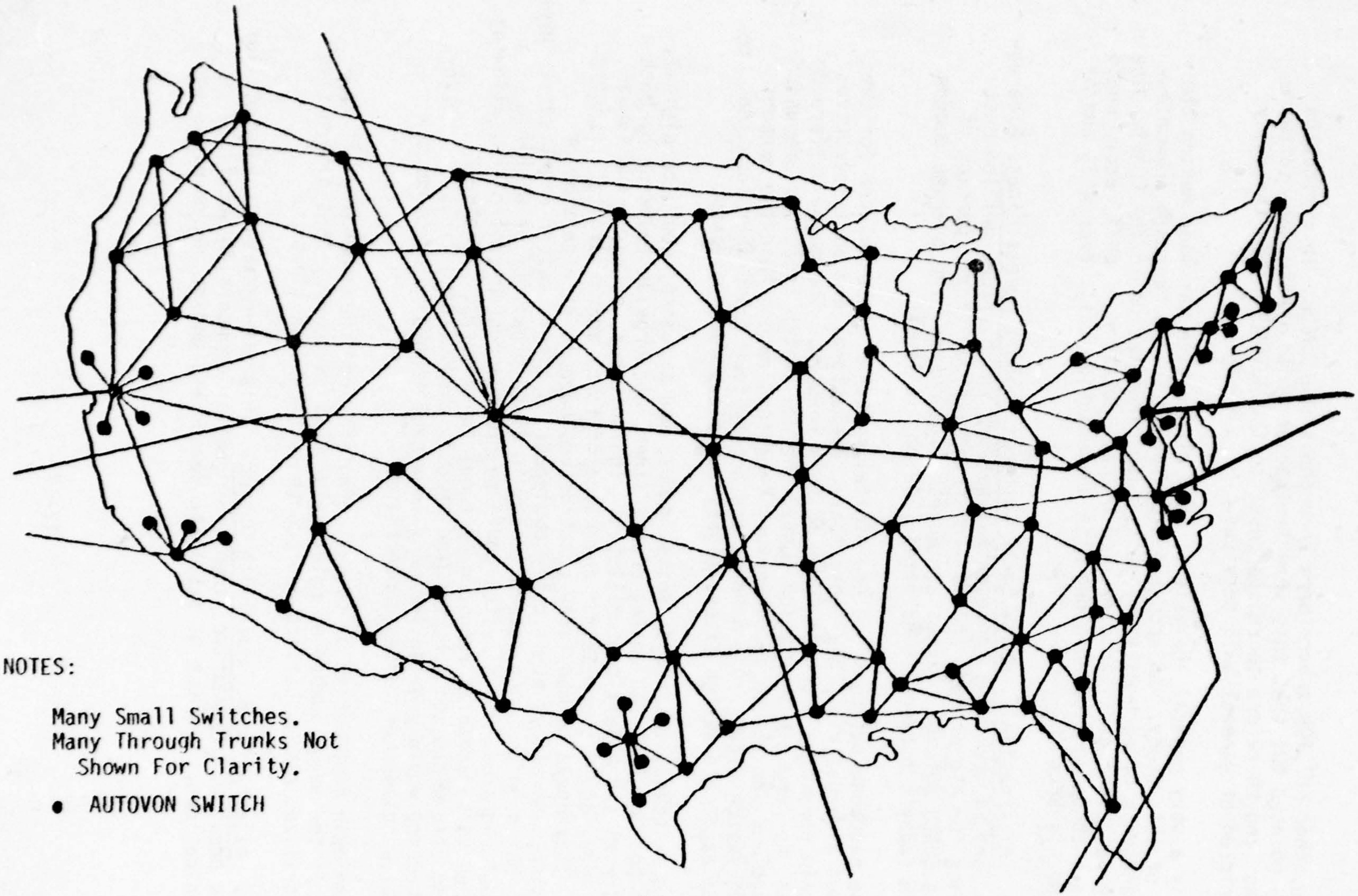
e. Alternative 5: Many Small Switches - Short Access Lines. Alternative 5 (see Figure IV-4) represents a network which trades off low cost switching for higher cost access line transmission. Forty percent of today's CONUS AUTOVON charges are access line costs. The average access line in today's network is 88 miles (142 km) in length.

The backbone switches are new digital switches as postulated for the previous alternatives. All subscribers, operational and administrative, are again served by a single CONUS AUTOVON network. The major difference is that, to reduce transmission costs, the new switch locations are unconstrained and are placed at subscriber locations rather than the present AUTOVON switch sites. One hundred and thirty four subscriber locations are used as candidate switch sites; eighty two sites were selected.

The switches, located at posts, camps, and stations, would be digital, handle both digital and analog access lines, and provide trunking by both terrestrial and satellite facilities. The switches, being in the local plant area, could take maximum advantage of local access digital transmission. They could be modularly constructed, capable of expansion or reduction, and always efficiently equipped. A single switch might serve several remote PBX's on post, or several bases in close proximity or within a metropolitan area. Each switch would be stored-program-controlled, allowing features to be added as required by local subscribers. A network routing plan would again be handled through the CCS data links. A network architecture would provide for many long-haul trunks to preclude the excessive buildup of tandem connections.

The main distinction of this alternative from the preceding alternatives is the large number of relatively small switches. This alternative decentralizes communications and shortens the access lines.

f. Alternative 6: Satellite Option. This alternative is very similar to the previous alternative except for greater emphasis on satellite communications. The use of satellite demand assignment and numerous small



NOTES:

Many Small Switches.
Many Through Trunks Not Shown For Clarity.

• AUTOVON SWITCH

Figure IV-4. Alternative 5

ground terminals is assumed to provide long haul communications. A terrestrial network using small digital switches at subscriber locations continues to provide additional communications capabilities for the operational users and short haul communications for administrative users. The terrestrial network provides MLPP features and interconnects with the overseas AUTOVON (see Figure IV-5) as did the small dedicated networks of Alternatives 3 and 4.

In this option, a small satellite terminal may be located at each switch. Satellites in the other alternatives may be used as "cables in the sky"; here, they would be used more to achieve the effect of a fully connected network with each satellite terminal directly connected with each other satellite terminal. There would be no need for multiple satellite hops within the coverage area of the satellites. Interconnection would be via channel assignment, which would be handled dynamically using demand assignment multiple access schemes in conjunction with the equivalent of a CCS network which would also be tied in with the terrestrial CCS.

The Satellite Business Systems (SBS) is an example of a system using this type of approach. A leased system, a government-designed and managed network, or some combination might be considered. CCS data links and a network architecture will provide for many through trunks in order to preclude excessive buildup of tandem connections. This concept also decentralizes communications and shortens the access lines.

All operational subscriber access lines were terminated on terrestrial switches. Access lines from each administrative subscriber location were terminated on both a ground terminal and a terrestrial switch in the same ratio as that of the "long-haul" and "short-haul" traffic being generated by that location. A different minimum-cost network could be designed for each breakpoint corresponding to the split of administrative traffic between satellite and terrestrial transmission. Therefore, several minimum-cost networks were designed corresponding to mileage breakpoints beyond which administrative traffic would be carried by satellite. This was done to determine the satellite/terrestrial traffic mix which would provide the lowest total system cost. The corresponding terrestrial costs decrease as additional administrative traffic is carried on the satellite, with terrestrial cost leveling off at the cost of providing a terrestrial network servicing the operational subscribers when all the administrative traffic is carried by satellite. Based upon the transmission, switching, ground terminal and other costs which were used, it appears that the mininum cost system for this alternative can be achieved at the point where approximately 70% to 80% of administrative traffic is carried via satellite which corresponds to 300 miles (482 km). The results of these designs are described in Appendix C.

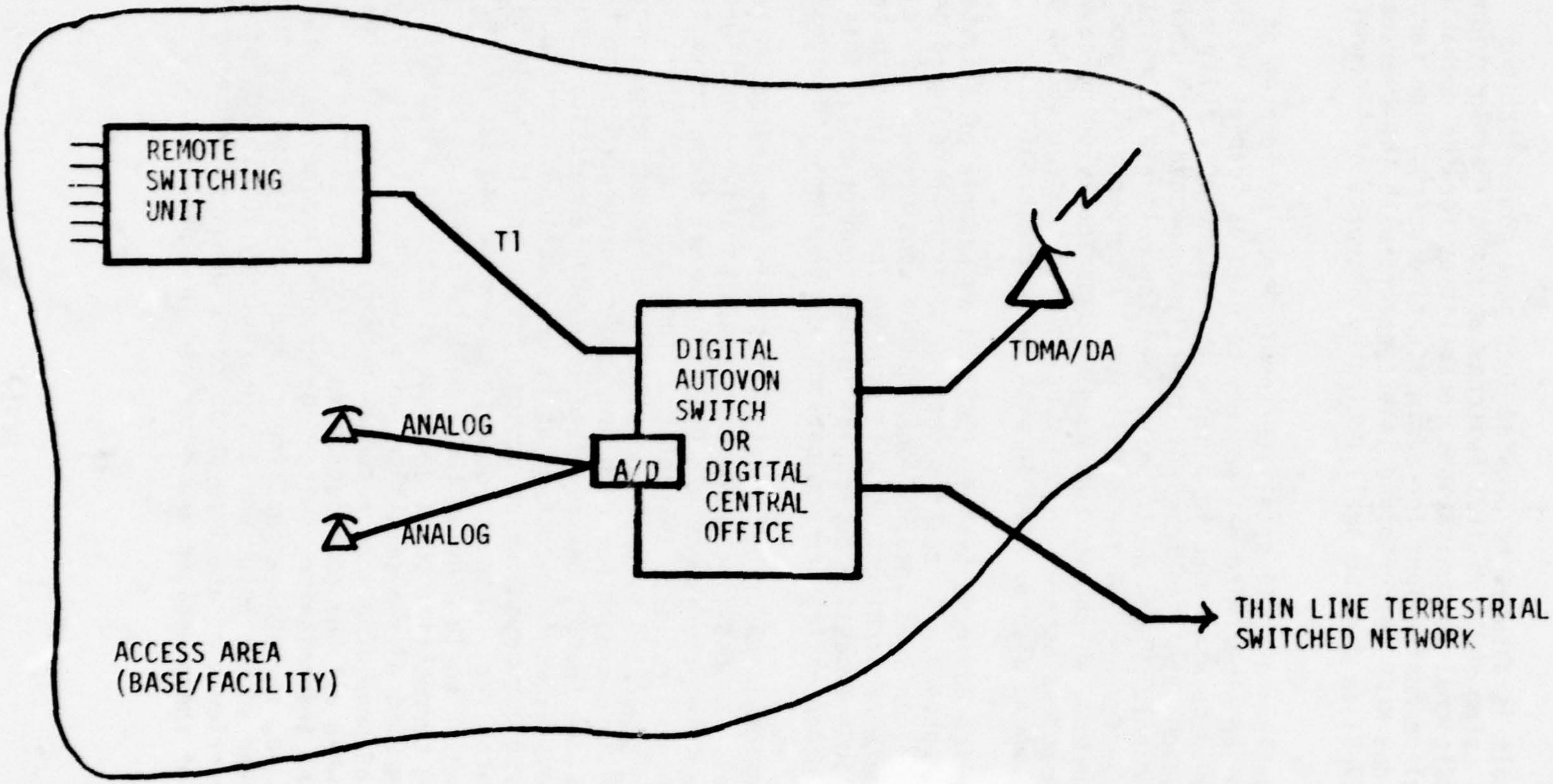


Figure IV-5. Alternative 6

6. ASSUMPTIONS AND CONSTRAINTS

Certain assumptions made in this study are listed here for convenience.

a. Time Frame In order to accomplish the network design and to develop costs over the 1982-1992 planning horizon, tariff estimates were required which would reasonably reflect what would be charged in this time frame. To simplify the computation process, 1985 was chosen as the technology, design, and cost base year. Thus, costs were developed and networks were designed as if all alternatives were implemented in 1985. In particular, the new digital switches and the satellite earth terminals represent what should be available in 1985. Other tariffed services such as the existing switches and existing transmission offerings were extended to the 1985 time frame.

The projection of existent tariff offerings to 1985 is based on considerations of the trends in previous years together with what can be reasonably expected to materialize in the 1978-1985 time period.

b. CONUS AUTOVON The primary motivation for this study was the increase in tariffs due to the SCAN revisions and the possible elimination of TELPAK. One of the largest customers of the present CONUS network is NORAD, which currently operates the Semi-Automatic Ground Environment (SAGE) system with heavy dependence upon eight Canadian switches in the Canadian Switched Network (CSN). NORAD is planning, however, to convert from the SAGE system to the Joint Surveilliance System (JSS) by 1982. The JSS has redefined the NORAD regions such that they will no longer span Canada and the U.S. boundaries. JSS sites will be homed to Regional Operational Control Centers (ROCC) within each country. There will no longer be any cross-border subscribers in the JSS in the time frame of this study. It was felt that the CSN would have little impact on the results of the study. Therefore, for purposes of limiting the study to prove the technological feasibility and economic impact, only the contiguous 48 states have been considered. Once the framework of this area has been developed, it can easily be expanded to include Canada.

c. Subscribers to CONUS AUTOVON

(1) Operational Traffic. A total network data base of 16,701 subscriber access lines for CONUS AUTOVON was developed from the current DCA Circuit Directory. Certain of these subscribers have missions highly related to the needs of national security. It is felt that these operationally oriented subscribers will rightly place demands for enhanced capability on the future AUTOVON which cannot be met by normal CONUS commercial communications alone. Consequently, it was necessary to partition the traffic matrices into two components (Administrative and Operational). Furthermore, two of the alternatives which are totally dependent upon the commercial network have been augmented with a small dedicated

network to provide the additional capabilities required of the operational traffic. The most significant features provided by this additional network are call completion in times of natural disasters, holidays, or other traffic overloads wherein the commercial network experiences unpredictable blockages, interoperation with the Overseas AUTOVON, network survivability, automatic conferencing, etc.

Operational subscribers were developed with a knowledge of the number of circuits whose "Purpose-Use" code in the DCA data base indicated an association with a certain operational network (e.g.; SAGE, NMCC, Army C^3). Secure voice subscribers were included in the operational network as well as selected special purpose users in the same data base. These users might opt for the switched services of AUTOVON to replace their dedicated networks of today. Appendix A provides the details on these operational network subscribers as well as discussing total AUTOVON requirements.

(2) Canadian Subscribers. The number and location of the Canadian switches seem to be strongly influenced by factors other than cost, such as Canadian National policy. Certain concepts used in the study, such as use of the No. 4 ESS and/or the WATS-type service, also do not appear applicable to the Canadian portion of AUTOVON.

The Canadian subscribers were treated, for network modeling purposes, as if they were collocated with their nearest Canadian AUTOVON switch. The present Canadian AUTOVON switches were then treated as subscribers to CONUS AUTOVON; intra-Canadian traffic was assumed to have no impact on the CONUS AUTOVON analysis. This was done in order to provide a more valid cost comparison among the various alternatives.

(3) Overseas Subscribers A small number of overseas locations (e.g., Ramstein, FRG) have access lines terminating directly on CONUS AUTOVON switches. Because of the long and costly access lines involved, these subscribers could unduly influence the switching center selection process toward locations near the coast of the U.S. The coordinates of all these overseas subscribers were changed, for network modeling purposes, to approximate CONUS international cablehead locations in an attempt to reduce this false bias.

d. Secure Voice Over AUTOVON. Secure voice subscribers are assumed to be an integral part of CONUS AUTOVON. These secure voice subscribers will obtain encryption based upon the National Secure Agency (NSA) work on the BELLFIELD family of equipment. These same subscribers can place clear voice or secure voice calls from the same terminal and are considered part of the Operational Network.

e. <u>Access to Overseas AUTOVON</u>. All CONUS AUTOVON alternatives were considered on a worldwide basis. That is, any given alternative must interoperate with any given overseas option as a single global network. In all alternatives, operational traffic will interconnect directly with the Overseas AUTOVON.

f. <u>AUTOVON Switch Costs.</u> The SCAN tariffs are utilized wherever the alternative assumes the use of existing CONUS AUTOVON switches. (See Appendix C for details).

The cost estimate for the commercially available digital switches is based upon a commercial Class 4/5 switch. A number of different commercially manufactured switches were investigated with regard to cost. Unique government requirements (MLPP conferencing, etc.), and their impact on software, effectively double the first cost of a switch. After applying the cost reductions due to projected improvements in LSI technology and escalating the costs to the baseline year (1985), an estimated installed cost per switch termination was established at $1500.

Currently, no tariff exists or has been developed by a common carrier to provide digital switched services for the CONUS AUTOVON. In order to develop such a tariff for costing purposes, it was necessary to assume that in the 1982-1992 time frame such services will be offered by the common carriers. It was further assumed that the tariff will reflect the cost of providing service, including maintenance, depreciation, etc., as a percentage of the installed cost or investment. The tariff was assumed to be approximately 40% of the installed costs. This would imply a 1985 tariff of $50 per month for each termination on a digital class 4/5 switch which amounts to about one-third the cost of an analog switch termination projected to 1985.

The No. 4 ESS switch (Class 4) line termination installed cost was estimated at $29 per termination. The tariff for the No. 4 ESS was again assumed to be approximately 40% of the installed cost. This cost also assumed 1985 tariffs with inflation offsetting technological costs.

While under current technology the cost per termination varies with the total number of terminations, a search of the technical literature reveals that in the 1980's time frame, the per line cost of switches over a wide range of sizes will not differ significantly. Technology will reduce or eliminate the existing economies of scale advantage of very large switches. Thus, for the CONUS AUTOVON study, the 1985 per line cost of new switches is assumed to be independent of the total number of switch terminations. Considering the fact that most of the AUTOVON switches have total terminations in a narrowly defined range, 500-1000, use of a constant cost per termination was considered reasonable.

g. Transmission Costs. The present day CONUS AUTOVON is charged for transmission under the TELPAK tariff which is furnished under court order. How long this arrangement will continue is not known. The AT&T Co. has filed for a Multi-Schedule Private Line (MPL) arrangement under Tariff 260 to become effective upon the demise of TELPAK. In terms of a 1985 tariff projection for this study, the only alternative to TELPAK was to use the MPL rates. The detailed cost and tariff considerations for transmission are found in Appendix C.

(1) Access Transmission Costs: An MPL Line tariff was used for the access area in all alternatives. The MPL charges listed were escalated to reflect 1985 costs. It was assumed that a subscriber collocated with a switch would incur no access transmission cost.

(2) Backbone Transmission Costs. The backbone networks, which serve the operational users exclusively, were assumed to use the MPL tariffs because they would be supported primarily by terrestrial transmission. For all other backbone networks, a combination tariff was developed based upon the use of satellite transmission for interswitch trunks (IST's) in excess of 800 miles (1287 km).

(3) Satellite Costs. Satellite point-to-point transmission will be more prevelant in the 1980's and may serve the CONUS AUTOVON long haul traffic in excess of 800 miles (1287 km). In excess of 2500 miles (4023 km), circuit costs are expected to be insensitive to distance, reflecting the fact that satellite transmission costs tend to be fixed and are not variable with distance. In the 1980's, backbone long haul transmission will be considerably less expensive than even the present TELPAK or MPL tariffs. For distances less than 800 miles (1287 km), the MPL tariff is assumed, inflated to 1985. For distances between 800 and 2825 miles (1287-4545 km), a satellite cost per mile tariff is used which reflects the existing tariff inflated to 1985. For distances in excess of 2825 miles (4545 km), a fixed charge of $916 is used which is the present tariff of $650 inflated to 1985. The rate of inflation through 1985 for the purpose of this study was assumed to be 5%/yr.

The cost elements of satellite services provided directly to the subscribers consist of the space segment, the earth terminals, and a network control required to provide a complete communications service. It is essentially an estimate of a service to be provided in the 1980 decade by one satellite carrier. The estimate is made because, while there are presently plans for such a service, no tariffs or preliminary cost data are currently available from companies contemplating providing such services. New designs are required which by the 1980 time frame will take advantage of technological cost/performance advances to develop an economically viable terminal. An estimate of the cost of such a terminal is developed from an analysis of the major components.

For the purposes of this study, technological cost performance gains are assumed to offset inflationary cost increases. Hence, $450,000 per earth terminal reflects a 1985 cost. Using the 40% annual factor developed previously to convert investment cost to a tariff, the monthly estimated tariff for an earth terminal is $15,000 in the 1985 period. The above cost applies for a terminal operating with one satellite transponder. In a system of multiple transponders, additional receiver chains, control and processing hardware, and software are required. These investment costs are estimated at $55,000 per additional transponder, which will require an additional monthly tariff of $3,000.

The space segment leases, developed from present tariffs, are shown below:

Number of Transponders	Monthly Cost/Transponder
1 or 2	$142,000
3	133,000
4 or more	125,000

While technology will undoubtedly lower the cost to construct and place into orbit a communications satellite by 1985, inflation can be expected to have a significant adverse impact. The 1985 projection is based on the assumption that the two opposing trends will nullify each other. Thus, the 1985 transponder tariffs are assumed to be equal to today's price.

(4) Wide Area Telephone Service - WATS Costs. In order to develop a cost estimate for WATS, it was decided to assume an average location which was typical of 24 of the 58 CONUS serving areas. Using the total of 4700 Erlangs and 12,171 administrative access lines, the typical location would have 23 subscribers and 8.8 Erlangs of busy-hour traffic. In order to compute a cost, both the distribution of traffic by WATS Band and the total number of lines required must be determined. The Erlang traffic distribution by distance is known and is presented in Appendix A. This information was then used to compute a weighted tariff for the average location for a full business day service. This weighted average WATS tariff is $1,429 per month per WATS line required. Using the Erlang B function for a P.045 GOS and 23 subscribers, the total number of WATS lines required per location is 13, or for the total 12,171 subscribers, 6897 lines are needed. the total monthly cost is $13,860,000 inflated to 1985 at 5%.

Because many subscriber locations already have WATS service, an incremental WATS cost was estimated. The data to develop this incremental cost are extremely hard to obtain. Because of consolidated billing, identifying actual locations which have WATS may not be possible. In order to estimate

the impact of existing WATS cost, it is noted that presently at the Pentagon switch there are 490 subscriber access lines and 38 WATS lines, mostly Band 1. Based on this limited sample, it appears that approximately 8% of the subscribers presently have a direct WATS access. Extending this to the 12,171 administrative subscribers, it is estimated that 974 of them already have access to WATS. This was used as the basis for computing an offsetting cost for these existing lines. Thus, the WATS cost of Alternative 4 represents a net incremental cost. Since WATS can access both DoD and commercial telephones, the cost of this alternative represents a service more encompassing than the existing AUTOVON service.

h. Common Channel Signaling. Common channel signaling (CCS) was a major consideration and an integral part of all the alternatives under study. CCS is a system for exchanging information between processing equipped switching machines over a network of signaling links instead of the voice path used in present inband signaling techniques. Signaling information is digitized and transmitted over a separate data channel. CCS has information-carrying capacity not available with conventional signaling systems. For example, CCS will allow AUTOVON to satisfy the operational requirements of currently provided special purpose networks. It will also provide faster call set up time (from 10 seconds to about 1 second) and faster release of equipment which reduces holding time of facilities. Other attributes include flexible utilization of satellite communications, while avoiding excessive links in tandem, status information on echo suppressors, network management and maintenance signals. Details of these and other CCS features are covered in Appendix B.

The simplest and most direct form of CCS is a direct signaling link between the processors of all switching centers having interconnected trunks. Such a configuration is known as "associated signaling"; i.e. the signaling link is associated with the specific trunk group. The associated signaling mode was utilized intentionally in the CONUS AUTOVON study, although sparce trunk loading shows this method to be uneconomical. The configuration, using a separate signaling network or "non-associative signaling", was impractical to model and to cost during this study. See Appendix B for details of CCS.

i. Network Design Methodology. In order to provide valid economic comparisons, each alternative was designed to the same performance standard. A least cost access area and backbone network was designed which provided a grade of service comparable with the present day AUTOVON (P.13). This process entailed the determination of the optimal number and location of backbone switches, cost of homing the subscribers to those switches (access area cost), development of a backbone switch-to-switch traffic requirements matrix, and finally the design of the backbone network including its associated cost. Appendix C provides details of both access area and backbone network design.

The access area design process determined the number and location of the switches which were used in each specific alternative. The following were required as inputs:

- Subscriber geographical locations and the number of AUTOVON access lines associated with each location.
- Candidate switch sites; showing their location, and basic capacity.
- Where applicable, the cost of adding additional terminations at a switch. This was generally of the form of a cost for a module consisting of 50 terminations.
- Incremental backbone network transmission cost which would be incurred by the addition of a switch.
- The cost of transmission (tariff), expressed as a function of mileage and a terminal cost for each end of the transmission line.

A heuristic aproach using a program known as an "ADD" algorithm was used to select switching sites. The access area design program is initialized by determining the "center of mass" (COM) of all the subscriber locations weighted by the number of lines, selecting the candidate switch closest to this center of mass, and computing the cost of homing all subscribers to this candidate switch. For each subscriber location, the current homing (i.e., switch identification) and cost of homing are retained.

The output of this program provides the total network access cost as well as the number of switches used, and the homing of all subscriber locations. The switches selected, the homing of the subscriber locations, and subscriber-to-subscriber traffic data (program input) are then used to generate the backbone switch-to-switch traffic requirements matrix. The switch location file and the backbone traffic matrix are then used as inputs to the backbone network design program.

V. ANALYSIS RESULTS AND PREFERRED SYSTEM ATTRIBUTES

1. INTRODUCTION

This section contains an overview of the basic AUTOVON approaches and summarizes the analysis conducted at DCEC on the six CONUS AUTOVON alternatives discussed in section IV. This section also discusses the preferred system attributes of each of the alternatives and briefly addresses the planning and implementation implications. The analysis documentation is quite voluminous and extensive, but necessary for reviewers who may wish to explore the detailed analytic assumptions, techniques, and results. The individual studies supporting the analysis are documented in the appendixes as follows:

- Appendix A, Methodology and data utilized for assessing future traffic requirements of CONUS AUTOVON.
- Appendix B, Common channel signaling and routing considerations.
- Appendix C, Network design and economic analysis.
- Appendix D, Survivability analysis.
- Appendix E, Network Management implications.
- Appendix F, System Attributes.
- Appendix G, Policies.

The major issue which drove the search for AUTOVON alternatives is network cost. Therefore, this section will deal primarily with the results in this area. Another significant issue is that of survivability. While this issue is difficult to analyze quantitatively, some preliminary quantitative results and network implications are also discussed.

2. RESULTS RELEVANT TO THE THREE BASIC APPROACHES

The three basic approaches, or courses of action, to the design of the next generation CONUS AUTOVON have been identified as 1) continue the present approach, 2) take advantage of new developments in the telephone companies, and 3) consider advanced concepts which might significantly alter the configuration of a private line switched network (switches and transmission dedicated to the user such as the existing AUTOVON). This subsection broadly summarizes some of the major findings relevant to the three approaches. First, some general results concerning cost and survivability of switched networks are addressed, and this is followed by brief discussions on cost and survivability.

a. Cost Versus Survivability in Private Line Switched Networks. A dedicated network (transmission and switching dedicated to a specified type of user) has a cost structure where the total system cost is relatively insensitive to the number of switches in the network. Figure V-1 illustrates this point and shows that the relative cost difference between 10 and 80 switches is not an overriding issue. The major cost of the network is attributable to transmission costs (partitioned between backbone and access areas). The number of switches in a network can be selected by criteria other than cost.

The key question is how to arrive at the preferred number of switches in a private line switched network, since system cost is relatively insensitive to the number of switches. Another important issue is survivability; an approach to a quantitative survivability analysis is presented in Appendix D. An interpretation of those results is presented here for the case of generalized switched networks in order to provide some insight into preferred network characteristics for the next generation CONUS AUTOVON.

The figure of merit used to quantitatively analyze the survivability of a network is its traffic carrying capability in damaged and undamaged modes with a fixed budget allocation for the system. The damage scenarios considered are the cases where 10, 20, and 30 switches are randomly destroyed. The results of the analysis are not dependent on how these switches are rendered inoperable.

Figure V-2 illustrates the results for a generic private line switched network where a $8.2 M/month budget, corresponding roughly to the total cost curve of Figure V-1, has been allocated. The horizontal axis refers to the traffic carrying capability of the undamaged network. The vertical axis refers to the traffic carrying capability of the damaged network. The family of curves represent the cases of 10, 20, and 30 switches destroyed, with no consideration given to where they are located. The analysis depends on averages and uniform traffic distributions.

The structure of the network is varied (under a fixed cost constraint) by changing the number of switches and reconfiguration of the transmission links. The number of switches is illustrated at several points along the curves. The diagonal line corresponds to the situation where the network is capable of servicing the same traffic load under both stressed and unstressed conditions.

The net result of this survivability analysis is that in the region of 5500 to 6000 Erlangs (a typical busy hour traffic load for CONUS AUTOVON), the preference is for approximately 50 to 150 switches in a private line switched network, in contrast to a number between 25 and 50.

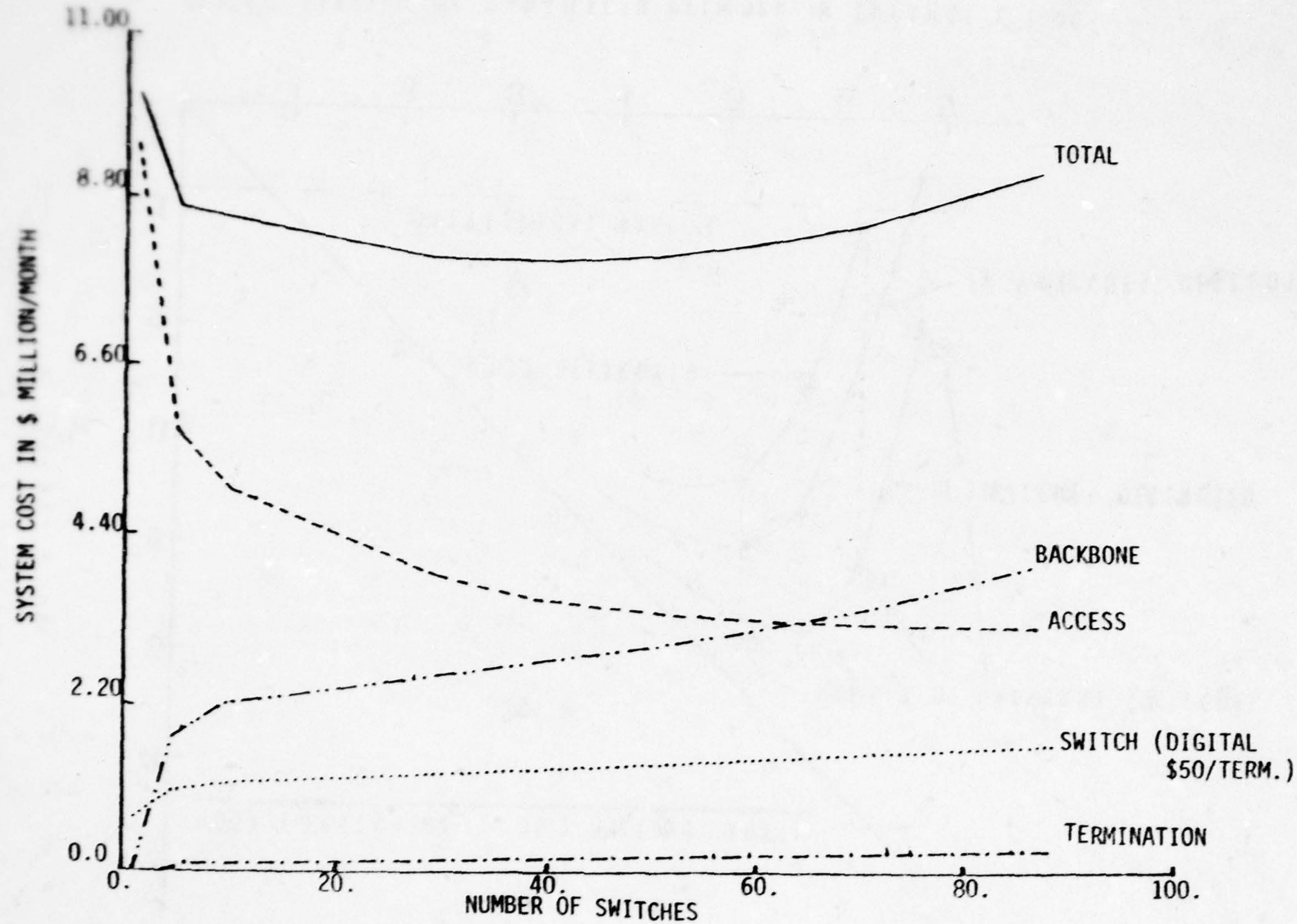


Figure V-1. Cost Vs. Number of Switches

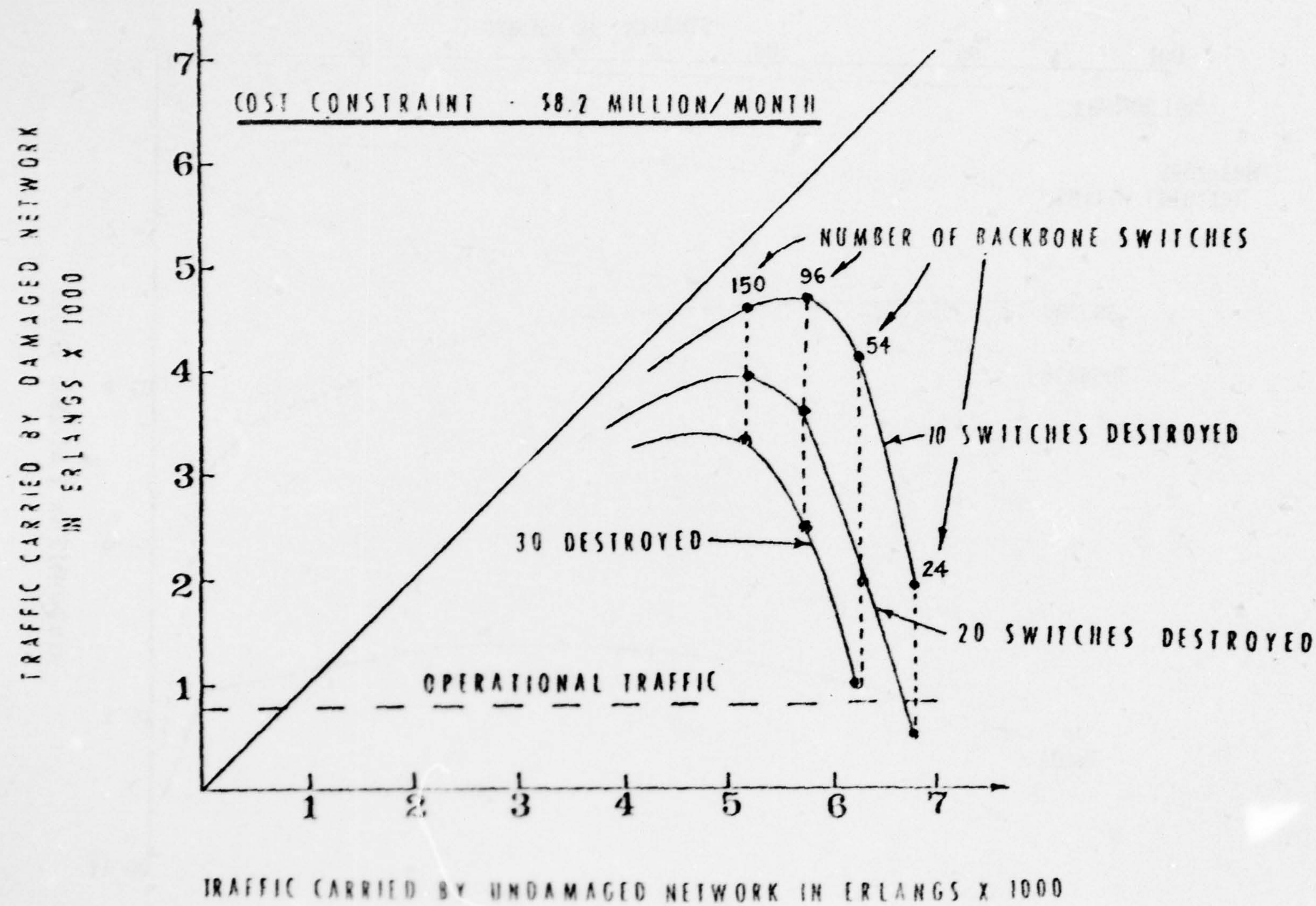


Figure V-2. Survivabilty Measure As A Function of The Number of Switches

The results also indicate that a considerable amount of network reconfiguration can be tolerated within a narrow cost range. There will be specific cases where removal of a switch has little or no impact on operational traffic and thereby effects a cost savings without an adverse impact on survivability. These situations must be handled on case by case basis.

The implications to AUTOVON are:

- From an overall system point of view, further switch closures in the present AUTOVON may not be preferred because the penalty in survivability is large compared to a small benefit in reduced charges. This is particularly true if all switches are converted to digital, thereby reducing the O&M costs (i.e., improved cost effectiveness). There are probably exceptions to this general statement where specific survivability aspects will have to be carefully considered on a switch by switch basis.

- A future AUTOVON which incorporates many switches, or appears to have many switches (virtual AUTOVON), and utilizes economical and diversified transmission could have significant survivability advantages.

b. Cost Implications. The costs for the three major design approaches for CONUS AUTOVON are shown in Table V-I. Designs which continue the present approach are based on combinations of Alternatives 1 and 2 over the 1982-1992 planning horizon. The TELCO developments reflect implementations of Alternatives 1, 3, and 4 over the planning horizon. The advanced concepts reflect mixes of Alternatives 1, 4, 5, and 6 over the 10 year period. The details of design, phasing, implementation, and costing are presented in section 7 of Appendix C. The range of cost, indicated by the low and high limits, reflects the options in which the basic approaches can be developed. All approaches begin with the baseline initially, then evolve to one or more of the CONUS AUTOVON alternatives associated with the design approach. Note that the advanced concepts, as well as continuations of the present approach, are in fact private line switched networks.

The costs shown in Table V-I represent the economic costs of the design approaches over the 10 year period. Each approach provides some potential for reducing annual AUTOVON charges of Alternative 1, the extension of the current AUTOVON into the 1982-1992 time period. The potential for cost reduction can be quantified by comparing the annual cost incurred when the design approach is fully implemented with the cost of the current AUTOVON with no change. This potential for reduction is also summarized in Table V-I for the three basic design approaches. By replacing the existing analog switches with digital switches, a potential reduction of 17% of the extended current AUTOVON cost is

TABLE V-I. TEN-YEAR LIFE CYCLE COSTS

DESIGN APPROACH	TEN-YEAR LIFE CYCLE COST * (MILLIONS OF DOLLARS)		ANNUAL COST REDUCTION POTENTIAL
	LOW	HIGH	
CONTINUE PRESENT APPROACH	$1,041	$1,124	17%
FOLLOW TELCO DEVELOPMENTS	$1,130	$1,144	11%
ADVANCED CONCEPTS	$ 924	$ 939	47%

* Economic worth at beginning of ten year period

possible. By taking advantage of TELCO developments as well as employing smart PBX's at the subscriber level for least cost routing, one can reduce cost by 11%. In the case of a WATS approach, however, there is a large benefit to be derived in that each subscriber with a WATS service has direct access to the commercial world. This should result in significant cost offsets; unfortunately this has not been quantified. The advanced concepts approach has a potential for reducing costs by 47%. Since all these reductions occur at different times within the 1982-1992 period, the economic worth of these reductions at the beginning of the 10 year period as presented in Table V-I does not vary drastically from one approach to another. The primary reason for this is that the reductions are only achievable towards the middle or end of the planning horizon.

In order for the reduction potentials to occur, certain changes in our present way of doing business must take place. Basic changes in current tariff arrangements must occur for all Alternatives except 1 and 4.

These results are based on the detailed results of the cost analysis for each of the six alternatives which also have inherent cost uncertainties. The individual results, and the uncertainties involved, are discussed in subsection V.3.

The net results of this macroscopic analysis have identified the following cost implications for a next generation CONUS AUTOVON:

- New network configurations based on advanced concepts have a 10-year life cycle cost advantage over continuing with the present approach.

- Basic changes in tariff structures must take place in order to take further advantage of the advancing technology, especially in transmission.

- Uncertainties in Telephone Company future services and tariffs have clouded the analysis of TELCO applications to the next generation CONUS AUTOVON. Because of the inherent economies of scale in the public toll network, options should be left open to reevaluate this area as uncertainties diminish.

c. <u>Survivability Implications</u>. The relative network survivabilities of two of the three approaches to the next generation CONUS AUTOVON are indicated in Figure V-3. These results are based on findings in Appendix D. The figure of merit for survivability comparisons is based on the capability of the network to carry traffic as a function of the number of nodes randomly destroyed. The advanced concepts approach provides the most survivable network, while continuing the present approach results in a less favorable performance. Depending on the point of view,

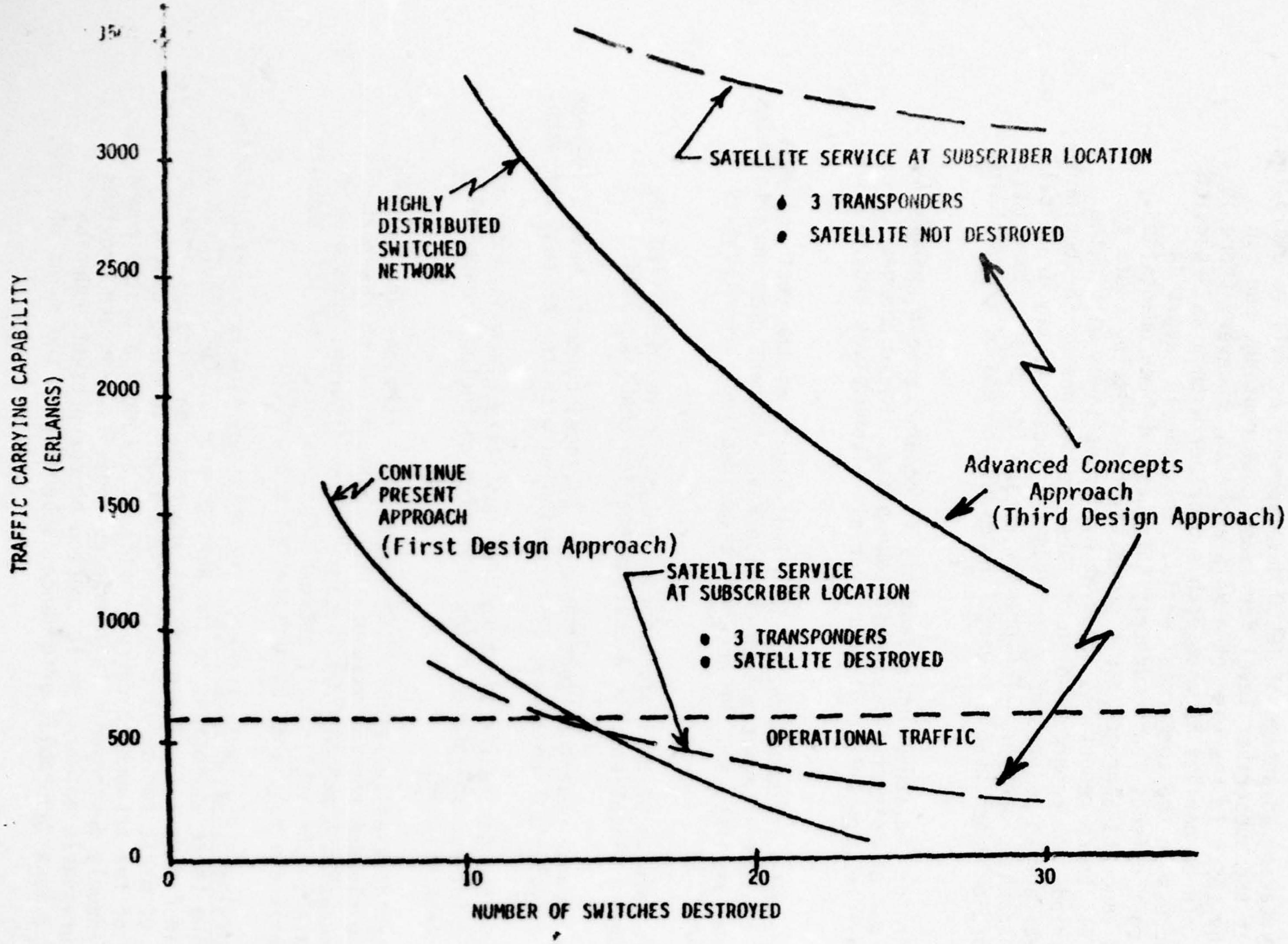


FIGURE V- 3. Network Survivability Comparison of Basic Approaches

NOTE: The Second Design Approach is omitted because the number of switches in this concept is dependent on the plans of AT&T and the Independents.

the approach utilizing TELCO developments is probably less favorable than continuing the present appoach due to the limited number of signal transfer points (for CCS) in the DDD network. On the other hand, one could argue that the diversity and magnitude of the DDD network should provide an enhanced survivability capability. The details of these issues are beyond the scope of this study.

Subjective survivability considerations are also presented in Appendix D. The primary survivability considerations for AUTOVON in the 1982-1992 time period are:

- The DCS AUTOVON (CONUS) should rely heavily on the common carrier grid.
- Communications resources do not have to be more survivable than the users.
- It is not practical to design DCS facilities to withstand blast from direct nuclear attack.
- Collateral blast damage avoidance should be a factor in locating switches.

3. COST AND SURVIVABILITY RESULTS FOR THE ALTERNATIVES

Table V-II summarizes, in simplified form, the cost and survivability implications relative to each specific alternative. Alternatives 6, 5, and 2 (in lowest cost order of ranking) appear attractive from the standpoint of cost, while alternatives 3 and 4 rate poorly in subjective survivability considerations as well as cost. The obvious conclusion based on these summarized results would be to initate a CONUS AUTOVON program to implement a system resembling the conceptual design represented by Alternative 6. However, a great number of uncertainties associated with the results make it inappropriate to come to such a simplistic conclusion. Furthermore, the original intent of the DCEC analysis was to explore a variety of uniquely different alternatives from which the attractive attributes and/or system characteristics of each would hopefully be synthesized into an overall conceptual design evolution for the next generation CONUS AUTOVON.

The cost analysis associated with each alternative used current tariff structures (inflated to 1985 values) to estimate terrestrial network costs. Cost estimation procedures were used to establish annual lease costs of satellite earth terminals and digital switches. It is recognized that new tariffs will have to be developed in the future to fully accomodate the various alternatives considered in this report. It is believed, however, that the use of current tariff structures in the

TABLE V-II. SUMMARY OF RESULTS

OPTIONS		CONTINUE PRESENT APPROACH		FOLLOW TELCO DEVELOPMENTS		ADVANCED CONCEPTS	
ALTERNATIVE NO.		1	2	3	4	5	6
COST	ESTIMATED COST/ YEAR IN 1985 DOLLARS (MILLION) (1)	$197	$139	$168	$188	$134	$92
	RANKING OF NOMINAL ESTIMATE	6	3	4	5	2	1
TECHNICAL RISK OF IMPLEMENTATION		LOW	LOW	MODERATE	MODERATE	MODERATE	MODERATE
SURVIVABILITY	COLLATERAL DAMAGE (NUCLEAR)	GOOD	GOOD	FAIR-GOOD	FAIR-GOOD	GOOD	FAIR-GOOD
	DIRECT ATTACK (NUCLEAR & OTHER)	FAIR-GOOD	FAIR - GOOD	FAIR	FAIR	GOOD	FAIR-GOOD

NOTES:
(1) The values listed are nominal estimates. See Appendix C for detailed treatment.
(2) See Appendix D for details.

Ranking is: GOOD
FAIR
MARGINAL
POOR

analysis will provide upper bounds on the total system cost of each alternative. The cost reflected in Table V-II is considered to be a nominal value for an upper bound system cost. Variations around this nominal value will take place due to uncertainties addressed later in this section. The uncertainties can be categorized into those that are quantifiable (e.g. inflation rate) and those that are not (e.g., new tariff structures).

The impact on the analysis results due to using current tariff structures is considered in the next paragraph. The intent is to show that system costs can be reduced by adapting tariffs to the technology and the user requirements (i.e., traffic characteristics and time of use). The subsequent paragraphs consider the survivability of private line switched networks, uncertainties in the analysis, and a summary of what has been learned about the next generation AUTOVON system based on the cost and survivability analysis.

a. Analysis Results Based on Current Tariff Structures. Within the framework of existing tariff structures, the options open to the DCA regarding the next generation AUTOVON are quite limited despite the improvements in cost per circuit mile and the reduced digital switching costs. Consider Figure V-1 where the monthly cost results are plotted as function of the number of switches. The transmission costs are based on MPL-AA and MPL-AB tariffs (rate center A to rate center A in the backbone and rate center B to rate center A in the access area), and digital switching costs are estimated to be $50 per termination per month.

The results indicate that, from a cost standpoint, the total network cost is heavily influenced by transmission costs and that the number of switches should be selected by criteria other than cost. These results imply that the highest cost payoff is to find ways of reducing the transmission related costs; however, with tariffs based on mileage (MPL, TELPAK, and point-to-point satellite tariffs to some extent), the overall structure of these curves will not be significantly altered.

A potential cost reduction in digital transmission (not reflected in the analysis) could result from using T1 or higher carrier bit rates where the digital switch is interfaced at the T1 level. This reduces costs at the switch as well as takes advantage of potential cost reductions due to new digital tariffs. New tariffs, achieved on a competitive basis, are not unprecedented. The recent implementation of 1.544 Mb/s satellite links provides an example. It is anticipated that significant cost improvements due to heavy competition among carriers and the rapid expansion of digital transmission technology which can provide economy of scale (e.g. satellite communications and fiber optic cables) will become more common in the future.

Alternatives 1 and 2, except for digital tariff uncertainties noted above, are not severely impacted by the current tariff structures since the network topology is similar to the existing AUTOVON with dedicated trunking and switching, as described in section IV. However, any benefits to be derived from configurations such as Alternatives 3, 4, 5, and 6 will necessitate new leasing and/or tariff arrangements.

One approach to reducing transmission costs within current tariff structures is to locate switches at major subscriber locations. Assuming that access line termination charges (those associated with transmission leases) no longer apply where switches are located on the premises, then the analysis indicates that access line costs can be reduced by approximately 50% with a nominal 12% increase in backbone transmission costs (see Table C-X in Appendix C). This approach was explored through analysis of Alternative 5, and the percentages cited above are in comparison to Alternative 2. The uncertainty with this approach resides primarily with the leasing arrangements of switches, and digital transmission. The relationship of DCA and MILDEPS on matters such as management and interface demarcation is also of concern and will have to be defined.

Alternative 5 exploits the use of many small digital switches and potential integration with base/facility communications. Additional cost benefits (as well as network survivability improvements) may result from local base/facility communications optimization due to sharing of resources. Alternatives 3, 4, and 6 also exploit sharing of resources to reduce costs; however, the tariff structure is unknown since such services are not presently offered.

Consider Alternative 6 where it is assumed that small satellite terminals are located at, or near, subscriber locations (possibly collocated with the digital switches of Alternative 5), and that some form of demand assignment is utilized for efficient sharing of the space segment. The introduction of this type of capability could result in decreased system costs as exemplified in Figure V-4 where cost is plotted as a function of the percentage of administrative traffic carried via the satellite service.

It is assumed that the tariff for this satellite service is distance independent and that the system adapts (via demand assignment) to variations with traffic. In other words, the satellite does not provide fixed point-to-point connectivity as currently tariffed by the carriers. The major uncertainty here is not the technology, but the tariff structure and the ultimate cost of such a system. For purposes of this study, a tariff estimate has been developed in Appendix C based on hardware and annual recurring costs.

The satellite system envisioned is a TDMA demand assigned system operating in the 11/14 GHz region to reduce interference problems

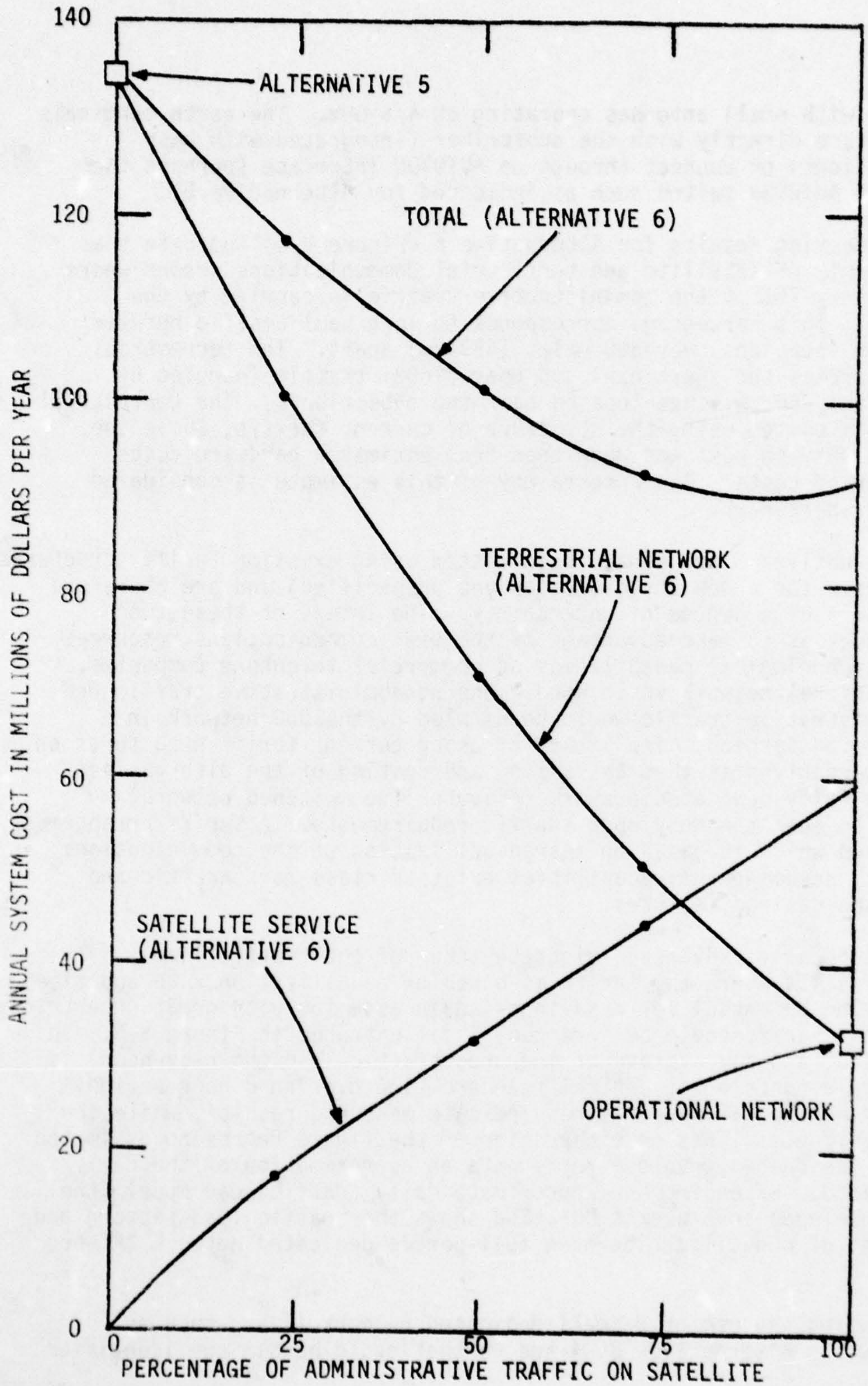


Figure V-4. Cost Versus Satellite Utilization

attendant with small antennas operating at 4/6 GHz. The earth terminals may interface directly with the subscriber (integrated with base communications) or connect through an AUTOVON interface (perhaps the collocated AUTOVON switch such as indicated for Alternative 5).

The costing results for Alternative 6 (Figure V-4) indicate the preferred mix of satellite and terrestrial communications occurs where approximately 75% of the administrative traffic is carried by the satellite. This percentage corresponds to long haul traffic between subscriber locations over 300 miles (483 km) apart. The terrestrial network carries the short haul and operational traffic (handled by approximately 60 switches located near the subscribers). The terrestrial network was costed using the structure of current tariffs, while the satellite service cost was developed from estimated hardware costs and recurring costs. The uncertainty of this estimate is considered in a later paragraph.

Alternatives 3 and 4 have been costed using existing tariff structures as estimates for a new structure (as yet unspecified) and are therefore subject to a high degree of uncertainty. The intent of these two alternatives is to take advantage of the vast communications resources and the technological capabilities of commercial telephone companies. The operational network would handle the nonadministrative traffic and the administrative traffic would be handled by the DDD network in a non-dedicated fashion. The impact of using current tariff structures on these alternatives is that the sizing and costing of the alternatives reflect a fully dedicated network (private line switched network) designed to meet the busy hour traffic requirements. A tariff arrangement is required which is based on shared utilization of the communications resources, assuming the capabilities exist to class mark traffic and provide the desired features.

Additionally, advantage might be taken of the traffic load characteristics where the tariff is based on a utilization rate and time of day. The potential for a savings (again assuming with great uncertainty that such a tariff could be arranged) is illustrated in Figure V-5. In this figure, a 5 day average of measured traffic load (hour-by-hour) is plotted as a function of central standard time over an 8 hour period. The solid horizontal hourly lines indicate measured results, while the dashed horizontal lines on either side of the figure represent estimated values. The dashed envelope represents an approximation of the daily traffic load. Extending the approximate daily traffic load model (the dashed envelope) to a week's duration shows the traffic load pattern and the amount of nonutilization of a full-period dedicated network (Figure V-6).

Assuming the use of a small dedicated network (i.e., such as envisioned in Alternatives 3, 4 and 6) that could handle the identified

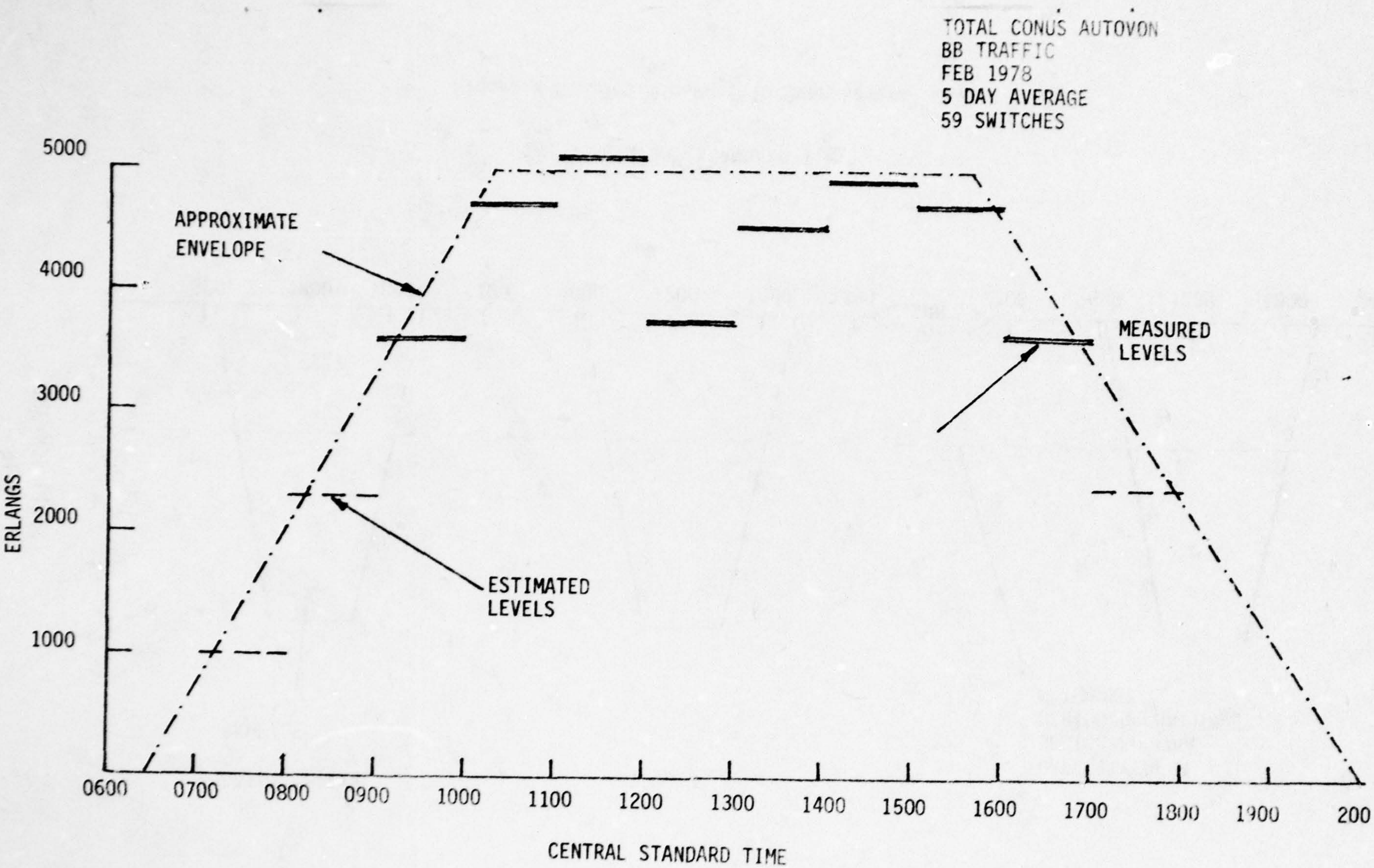


Figure V-5. Average Hourly Traffic Load

SERVICE UTILIZATION FACTOR = $\frac{5}{7}$ x (UTILIZATION PER DAY) $\approx$ 0.33

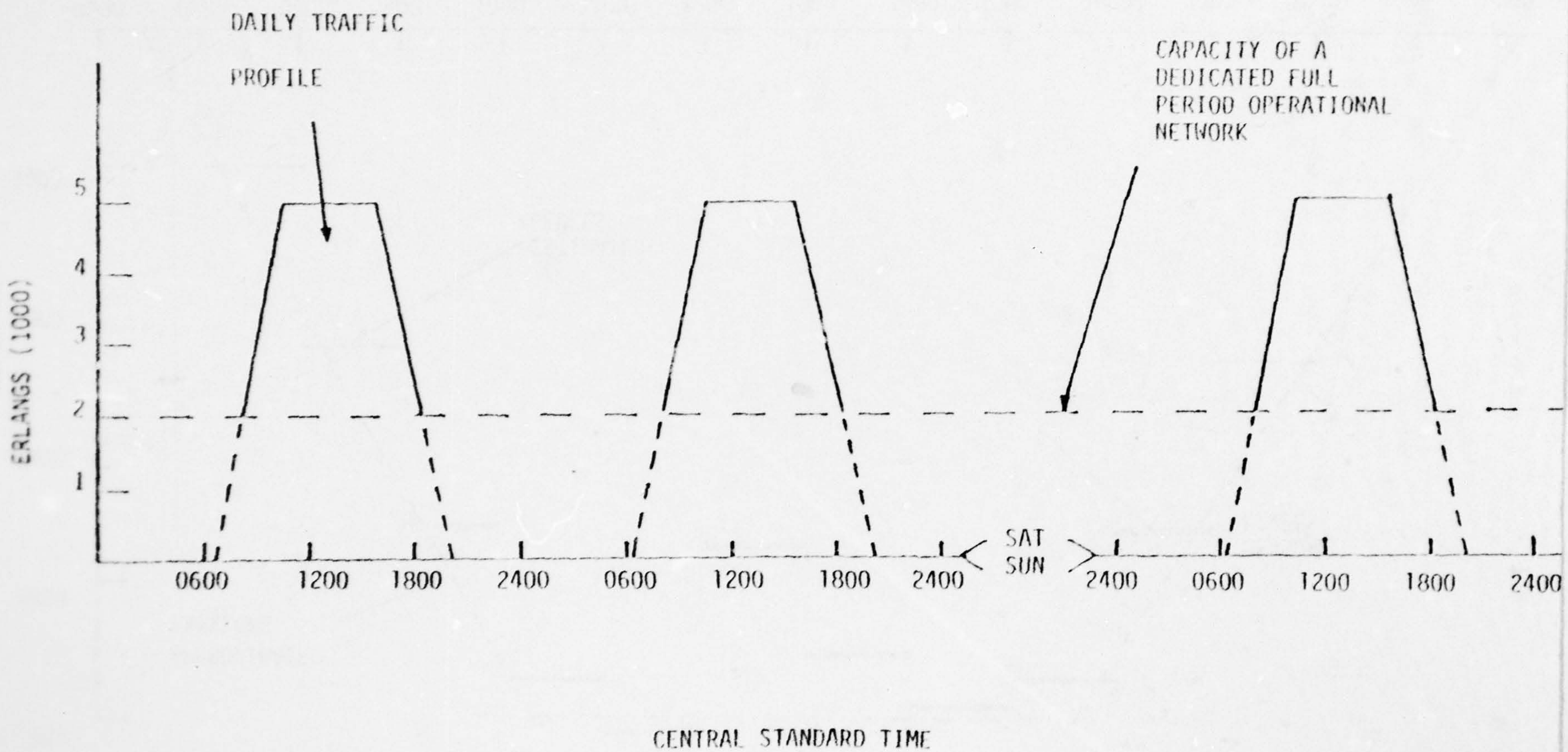


Figure V-6. Traffic Profile Over Several Days

AD-A070 703 DEFENSE COMMUNICATIONS ENGINEERING CENTER RESTON VA F/G 17/2
DESIGN CONCEPTS FOR THE NEXT GENERATION CONUS AUTOVON.(U)
DEC 78 R F DEARDORFF, W P DOTSON, T C HARRIS
UNCLASSIFIED DCEC-TR-18-78 SBIE-AD-E100 231 NL

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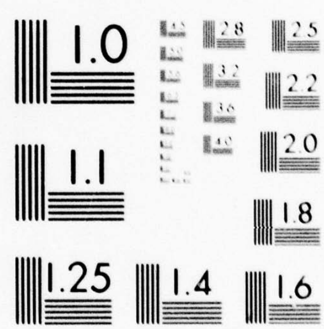

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

traffic, then the residual above the line could be offered to the commercial network on a usage basis. The large uncertainty with this approach precluded making any cost estimate of a new tariff; however, the potential for savings based on utilization rate (approaching 33%) makes this type of alternative worth pursuing in later studies rather than discarding it on the basis of cost at this time.

b. Comparison of Network Survivability. The relative network survivabilities of the alternatives are depicted in Figure V-7 in terms of carried traffic versus the number of switches randomly destroyed. These results are drawn from information supplied in Appendix D. The major findings include:

- Alternative 5 exhibits the best performance for the postulated switch damage scenario.

- Alternative 6 provides a graceful degradation of performance compared to Alternatives 1 and 2 (assumes the satellite is destroyed).

- A mix of alternatives configured to support the total traffic load may also provide graceful degradation properties. This approach has not been fully explored.

c. Uncertainties In the Analysis. As indicated earlier, the uncertainties in the analysis (primarily related to costing) can be categorized into quantifiable uncertainties (i.e., parameterization is possible), and those that are not. The quantifiable uncertainties are considered first.

(1) Quantifiable Uncertainties. Despite the fact that many of the uncertainties cannot be explicitly accounted for, some factors can be dealt with by classic approaches of economic analysis. This involves considering the range of values that a variable may take and applying sensitivity analyses to determine which variable may have a large influence on results. Within this framework, network design and economic analysis were performed on each of the six alternatives and the results are depicted in Figure V-8. The details of this analysis are presented in Appendix B.

The most significant quantifiable cost influencing factors are those of relative inflation rate, digital switch cost, transmission cost and earth terminal cost. These factors are listed in Table V-III along with the estimated variability. The combined results of these uncertainties are reflected in the high-low cost estimates for each alternative in Figure V-8.

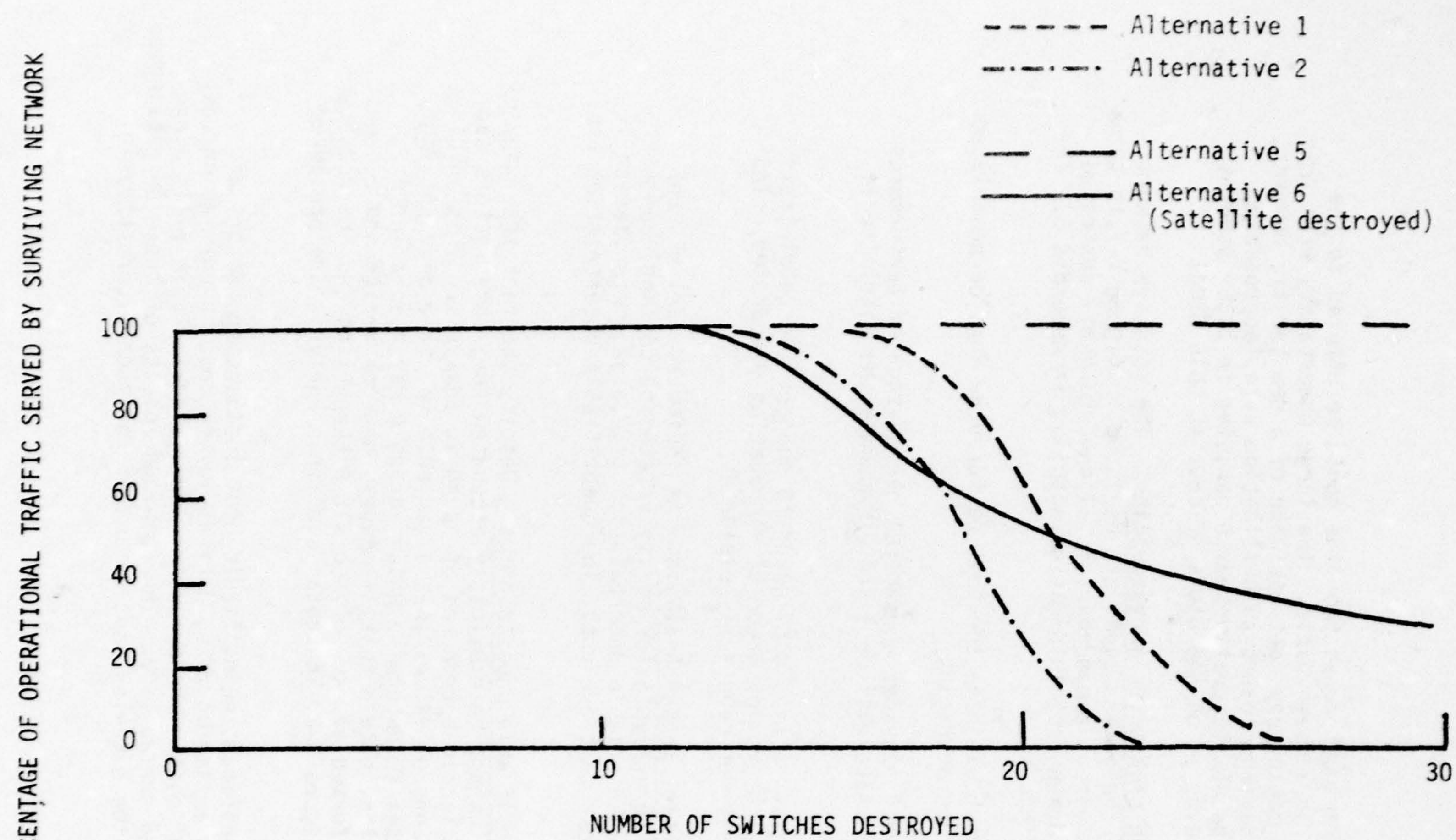

Figure V-7. Network Survivability Comparison of Alternatives

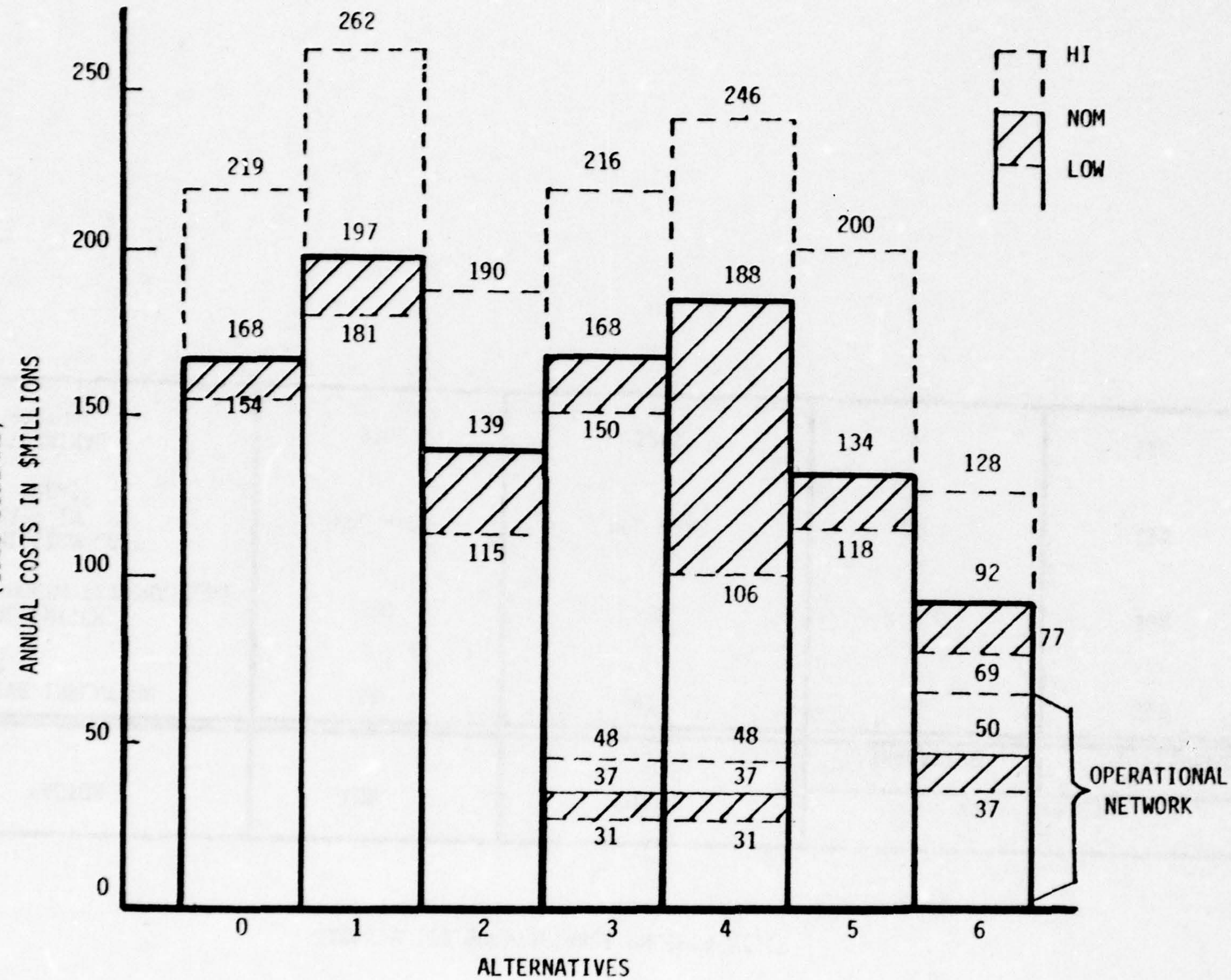

Figure V-8. Cost Comparisons of Alternatives

TABLE V-III. QUANTIFIABLE UNCERTAINTIES

FACTOR	LOW	HIGH	MAJOR IMPACT	
			ALTERNATIVE	DIFFERENCE
RELATIVE INFLATION FACTOR	5%	9%	5	39%
DIGITAL SWITCH (COST/MONTH TERMINATION)	$20	$80	2,5,6	30%
TRANSMISSION COST (MPL RATE IN ACCESS AREA)	MPL - AA	MPL - AB	2	11%
EARTH TERMINAL (COST/MONTH)	$10K	$20K	6	12%

Inflation applies to all alternatives and is made up of a nominal 5% compound rate that takes into account technological cost improvements in the time period up to 1985. An upper limit for this rate is estimated to be 9%, which reflects the situation where technological cost improvements do not influence the current annual 9% inflation rate for telecommunications costs. This increase impacts Alternative 5 the most with a 39% increase in total cost.

A major cost issue concerns digital switches where the hardware costs vary over a range of approximately 30%. The additional uncertainty in the tariff to carrier cost ratio (0% to 30%) results in switch tariff estimates ranging from \$20/termination/month to \$80/termination/month. The major impact of switch cost is in Alternatives 2, 5, and 6 where a variation of about 30% is experienced. The lower value of switch cost is partially due to reduction of costs relevant to current MLPP implementations which may be changed or simplified using the capabilities of new digital switches and CCS. The contributions to overall cost by MLPP and CCS capabilities are shown in Figure V-9. The CCS cost is made up of processor, software, termination equipment, and transmission mileage costs based on a fully associated CCS system. The software and termination equipment costs could be drastically reduced if commercial venders make this a standard package which also satisfies the needs of DoD (this reduction in cost is not included in Figure V-8). Also, it is apparent that the fully associated CCS is not preferred for alternatives 1 and 5; however, optimization of a CCS system was not included in this study.

An additional factor leading to possible total system cost uncertainties is that the switch cost per termination is assumed to be independent of the switch size (i.e., 100 switches with a 20,000 line network capacity have the same total switch cost as 25 switches for the same 20,000 line network capacity). This assumption affects the relative cost comparison of Alternatives 2 and 5. Preliminary indications are that the per termination costs of digital switches are relatively constant over a range of several hundred to several thousand terminations per switch.

The uncertainty in transmission is predominantly due to not knowing whether a subscriber is located in a specified rate center for the MPL tariff and uncertainty in applying existing WATS tariffs to Alternative 4. The uncertainty in MPL rates is applied to the access area where nominally a MPL-AB rate was assumed. A decrease in access transmission costs (up to 11% for Alternative 2) results when MPL-AA rates are assumed. The variation in WATS costs are due to assumptions on the number of WATS lines (i.e., GOS considerations) provided in Alternative 4 (see Appendix C).

Since earth terminals and transponders operating in the 11-14 GHz frequency band are not currently in production, the tariff estimate of a satellite service using demand assignment is uncertain at this time.

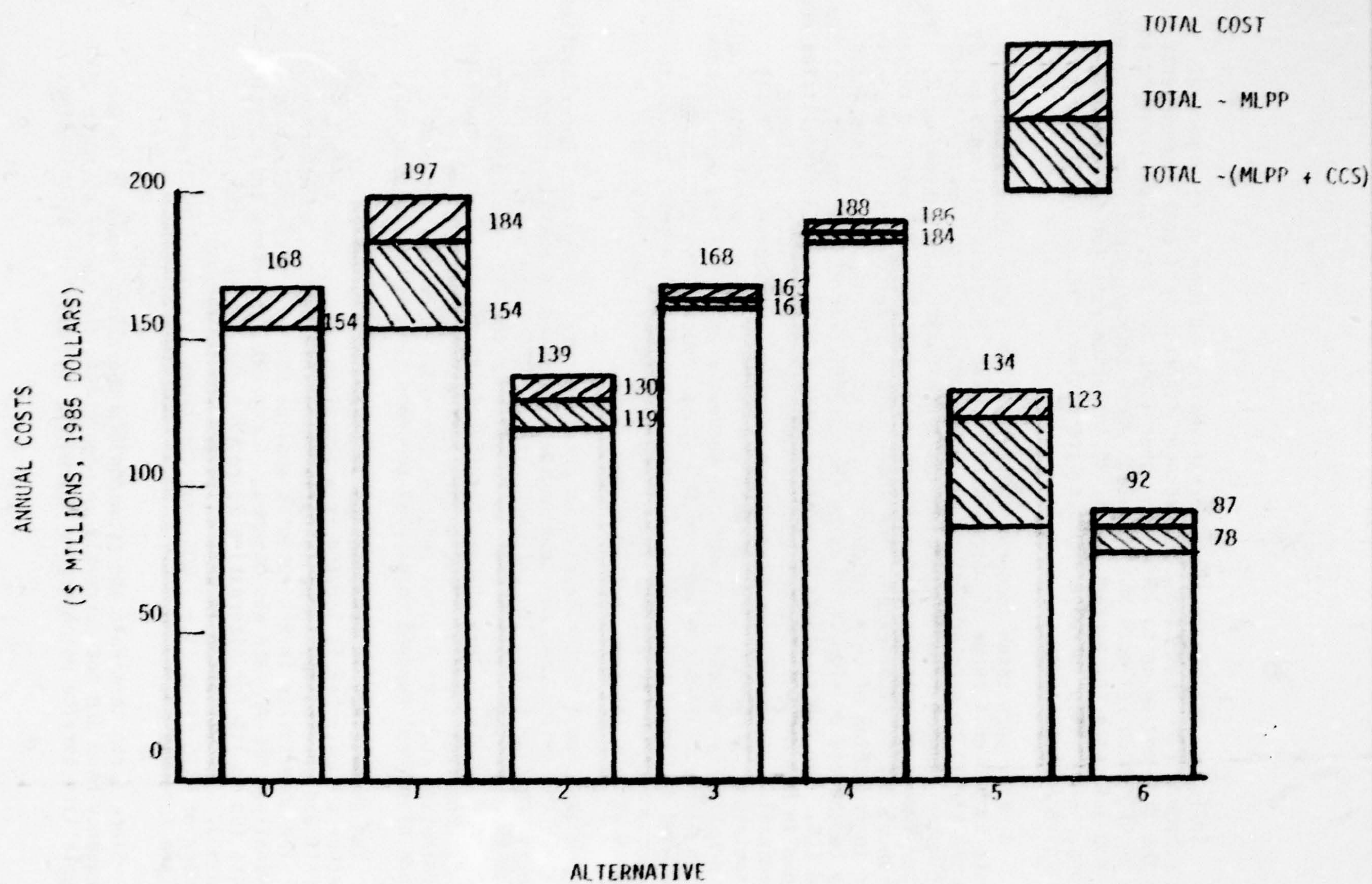

Figure V-9. Sensivitity of Alternatives to Associative CCS and MLPP Costs

As discussed in Appendix C, the monthly cost of an earth terminal can range from $10K to $20K per month. Additionally, a cost of $3K/month is added to each earth terminal for every additional transponder the terminal has to operate with. Using these cost figures, and assuming space segment costs are similar to today's tariffs, the uncertainties of satellite services are reflected in Table V-III. The resulting 33% total cost uncertainty of an earth terminal reflects an overall uncertainty in Alternative 6 of 12%. This result is for the case where administrative traffic destined for over 300 miles (483 km) is carried by satellite.

(2) Nonquantifiable Uncertainties. This category of uncertainty is characterized by whether or not a change or new arrangement can be initiated in a timely manner (e.g., new tariffs), or by the lack of definitive data for obtaining quantifiable analytic results (e.g., survivability). The major uncertainties are listed in Table V-IV which also indicates the nature of the uncertainty relative to the alternatives. Among the alternatives considered, Alternatives 1 and 2 can be implemented without basic changes in tariff arrangements, except for new digital tariffs in Alternative 2. In order for Alternatives 3 and 4 to become attractive from a cost point of view, departures from the current tariff arrangements (including the WATS tariff) must occur. Changes could occur through the use of classmarks in the commercial system which would permit DoD to take advantage of the economies inherent in a public network, and at the same time satisfy its unique communications needs.

The implementation of Alternatives 5 and 6 assumes that certain types of tariff arrangements will be possible in the 1982-1992 time frame with respect to digital switches and small satellite terminals. Whether the details of such arrangements can be worked out is considered speculative at this time and dependent on the future regulatory environment. However, DCA must assume some active role in insuring that the desired changes do occur.

DoD policies, such as JCS MOP's and DCA Circulars, are based on the technology of the current AUTOVON. This is also true of the current AUTOVON Interface Criteria and the present doctrine by which DCA exercises operational direction and management control. The constraint of these policies would have to be lifted in order for cost-effective variations of Alternatives 3, 5, and 6 to be feasible. If changes to these policies cannot be effected, then it is fruitless to consider these alternatives.

The alternatives explored by DCEC are not classic alternatives that are mutually exclusive and which can be implemented at the same point in time. For example, it is possible with a concerted effort, to implement Alternatives 1 and 2 before 1985. However, it is doubtful that Alternatives 3, 5, and 6 could be implemented by 1985 because of the nonquantifiable uncertainties discussed above.

TABLE V-IV. NON-QUANTIFIABLE UNCERTAINTIES

UNCERTAINTY	AUTOVON ALTERNATIVES					
	1	2	3	4	5	6
NEW TARIFF/LEASING ARRANGEMENTS	N/A	LEASED DIGITAL SWITCHES AND TRANSMISSION	UTILIZATION RATE OF A SHARED RESOURCE	WATS	LEASED DIGITAL SWITCHES AND TRANSMISSION	LEASED DIGITAL SWITCHES & SATELLITE SERVICE
POLICY CHANGES	N/A		DOD AND JCS POLICY REVISION			
CHANGES IN INTERFACE CRITERIA AND STANDARDS	N/A		FUNCTIONAL/SOFTWARE INTERFACE VS LOCATION/PHYSICAL INTERFACE			
CHANGES IN THE ROLE OF DCA	N/A		OPERATIONAL DIRECTION AND MANAGEMENT CONTROL			
TIME FRAME OF FULL IMPLEMENTATION	BY 1985		POST 1985 - LIMITED BY THE FOREGOING UNCERTAINTIES			
SURVIVABILITY	A SUBJECTIVE EVALUATION HAS BEEN COMPLETED					

Many survivability factors cannot be quantified because they are dependent on the intent of an enemy, his perception of our vulnerabilities, and his subjective application of finite resources. This is a difficult element to express in precise numerical terms. The qualitative ratings provided in the survivability analysis results presented in Table V-II are highly aggregated. A more detailed treatment is provided in Appendix D. The implications of network survivability on a quantitative basis are presented in paragraph V,3,b. The above uncertainties are inherent in those results.

d. Insight Provided By The Analysis. Despite the shortcomings of the analysis with regard to cost uncertainties and the generalized survivability implications, inferences can be drawn from the results which provide insight on the direction to proceed with the next generation CONUS AUTOVON.

The net result, from a cost and survivability standpoint, is that in the face of uncertainty, Alternatives 6, 5, and 2 are the favored alternatives. The common thread among these are that they represent private line digital switched networks. A possible disadvantage of Alternative 2 could be the limited number of switches; however, this may be offset by the switch locations (existing AUTOVON switch sites) which provide some survivability enhancements.

In the event that tariff and implementation uncertainties are reduced to an acceptable level, then Alternatives 3 and 4 could become cost competitive with the other alternatives. Additionally, a modification to the way in which Alternative 3 was defined would result in a more favorable cost for this alternative even within the current uncertainty. This could be accomplished by allowing subscribers to access the No. 4 ESS's via a Local Office (Class 5) or from an on-base central office or AUTOVON switch. The cost of Alternative 3 is then estimated to fall roughly at the Alternative 5 and/or 2 cost level since the basic network structure is similar even though it is not totally a private line switched network. The diversity of the DoD system enhances the overall network survivability when considered as another media to provide enhanced connectivity capabilities.

The approach to obtaining communications services in CONUS needs to be reexamined. The cost reducing benefits of digital technology will not necessarily be reflected in future tariff offerings, especially for terrestrial networks. In order for the DoD to avail itself of these benefits, approaches other than through existing tariffs will have to be explored. For example, desired transmission services could be obtained through the competitive processes with the least cost bidder then filing a tariff for the necessary service. Digital switches and earth terminals for Alternatives 5 and 6 could be obtained competitively through third party leasing arrangements. The method of acquisition is therefore as much a design parameter as switch location or grade of service in designing CONUS AUTOVON.

In summary, the cost and survivability analysis results indicate the following:

- Private line (i.e., dedicated trunking and switching) digital switched network alternatives provide the least cost implementation of AUTOVON based on current knowledge of tariffs.

- DCA should address DoD policy and internal DCA guidance in view of the emerging regulatory and technological environment.

- DCA should assume an active role in insuring that the preferred tariff structures are established.

- Satellite services with earth terminals located at the subscribers have potential for a significant cost savings.

- A distributed network with on-base switches is preferable from a network survivability point of view due to the large number of switches. Access to the DDD network from the subscriber level would enhance survivability performance because of the diversity of the system (a virtual AUTOVON with many nodes).

- Local communication optimization at the Base/Facility level could have favorable cost impact on CONUS AUTOVON.

4. PREFERRED SYSTEM ATTRIBUTES

This subsection attempts to compile the system characteristics, features, and potential handling capabilities of the preferred alternatives. The intent is to identify the major attributes of the next generation AUTOVON, but to leave some options open for taking advantage of new technical developments and tariff structures.

a. System Characteristics. While uncertainties abound, several things are relatively clear; a comparison of Alternatives 1 and 2 leaves no doubt regarding the economies of digital switching, and a comparison of Alternatives 5 and 6 indicates the desirability of a demand assigned satellite service available at or near the subscriber locations. Recall that these are the only unique differences between Alternatives 1 and 2 and Alternatives 5 and 6 respectively. Note also that the only unique difference between Alternatives 2 and 5 is the location of switches. While there is little cost difference between these two alternatives, it should be kept in mind that all alternatives were costed assuming full associated CCS. This is a severe penalty for Alternative 5 which has more than twice as many switches as Alternative 2. Under the presumption of an optimized CCS scheme, Alternative 5 has more potential

TABLE V-V. PREFERRED ATTRIBUTES BASED ON COST AND SUBJECTIVE ANALYSIS

	CATEGORY	CONTINUE PRESENT APPROACH		FOLLOW TELCO DEVELOPMENT		NEW ADVANCED CONCEPTS	
	ALTERNATIVE NO.	1	2	3	4	5	6
COST COMPARISON	SWITCH TYPE (ANALOG VS. DIGITAL)	-	DIGITAL PREFERRED				
COST COMPARISON	SWITCH LOCATION		-			LOCATION AT SUBS PREFERRED	
COST COMPARISON	PT-TO-PT SATELLITE BB TRUNKING VS DEMAND ASSIGNED SERVICE AT SUBS					-	SATELLITE DA PREFERRED
SUBJECTIVE COMPARISON	DIGITAL SWITCHED NETWORK WITH LEAST UNCERTAINTY		TARIFFS AND POLICIES LEAST AFFECTED				
SUBJECTIVE COMPARISON	SURVIVABILITY (DIRECT ATTACK)	FAIR-GOOD	FAIR-GOOD	FAIR	FAIR	GOOD	FAIR-GOOD
SUBJECTIVE COMPARISON	TIMELINESS OF IMPLEMENTATION	EXISTING	PRE 1985	POST 1985	1982-88	POST 1985	POST 1985
SUBJECTIVE COMPARISON	POTENTIAL FOR COST REDUCTION			HIGH, BUT SUBJECT TO REFLECTION IN TARIFFS	POTENTIALLY GOOD	TECHNOLOGY MAY FURTHER REDUCE COST	TECHNOLOGY AND COMPETITION MAY REDUCE IT
SUBJECTIVE COMPARISON	POTENTIAL FOR INTEGRATED SERVICES			GOOD		GOOD	VERY GOOD

for a cost reduction than Alternative 2 and therefore indicates the desirability of locating switches at or near the subscriber.

Pursuing this approach further results in the identification of preferred system attributes which identify, in broad terms, the overall structure of a next generation CONUS AUTOVON. Table V-V indicates these attributes as determined by cost and subjective comparison between alternatives. Generally speaking, the evolutionary trend of AUTOVON should preferably lead to a digitally switched network with switches located at or near the subscribers, small satellite terminals with demand assignment capability for long-haul traffic, and cost sharing services of the TELCO developments assuming a reduction in the associated uncertainties. A detailed discussion of system attributes is provided in Appendix F, which goes beyond the assessment outlined here and exploits the advantages of digital technology. The motivations for use of digital technology include:

- Low cost
- Ease of protection and encryption
- Consonance with developments in large scale integration
- Reliability and maintainability
- Remote performance monitoring techniques.

The attributes of the next generation CONUS AUTOVON are summarized below:

- Predominance of digital switching (at all levels of the switching hierarchy) and short-haul digital transmission. Long-haul transmission is digital via satellite but analog via terrestrial microwave system until commercial digital service becomes available. Digital transmission elements should be protected (i.e., bulk encrypted).
- Use of off-the-shelf hardware/software to the maximum extent possible. Special software/firmware may be required for unique applications.
- Lease of available services and facilities to avoid long lead time and costly military specifications.
- Multiple homing from a base/facility digital PBX, or central office to an AUTOVON mix of media consisting of satellite services, access to the DDD network, T1 tie trunks to other local switches, and T1 interconnects to a regional AUTOVON

switch to achieve a survivability level commensurate with the users.

- Access area software control for least cost routing and survivability enhancement.

- DCA could exercise operational direction by a dynamic "nail up" capability. System control should be characterized by distributed local control in peacetime, centralized control in crisis, and elements of both in wartime.

- DCA should exercise management control (network administration) with the assistance of automatic message accounting systems implemented at the switches.

- Technical controls and terminating facilities could be virtually eliminated and their functions performed by the digital switches. Special purpose circuits would not need to be manually wired at frames or patched at patch bays but could be "nailed up" by the digital switches if necessary.

- New cost-sharing arrangements should be developed to eliminate the adversary nature between overall system grade of service versus minimization of funding for access lines.

- Economical trunking service could be provided to AUTODIN, secure voice, and Special Purpose Network users.

b. Services and Features. The special services and features of the present CONUS AUTOVON are provided by the backbone switches of the network and consist of the following:

- Multi-level Precedence Pre-emption (MLPP)
- Conferencing
- Off-hook service
- Priority diversion
- Precedence Alerting
- Automatic traffic overload protection.

By utilizing commercial off-the-shelf hardware and modified software/firmware, it is technically feasible to provide most of the above features, and a host of others, at switch or concentrator locations

near the subscribers. Examples of additional features and services (see Appendix F for further details) include:

- Voice message storage
- Remote call forwarding
- One number INWATS for special functions
- Privacy service
- Alternate voice/data up to 56 kb/s (e.g., high speed facsimile.)
- Digital service for secure voice AUTODIN and other special users/networks.
- The quality of service (echo, noise level, etc.) for users would be equal to or better than what is experienced over the public telephone network today.

The use of satellite services at selected subscriber locations offers additional services and capabilities. The above features can be handled in a demand assigned satellite network as well as a terrestrial switched network. Additional capabilities include:

- Integrated digital voice, data, and image transmission
- Wideband data (56 kb/s and above)
- Video conferencing
- Private networks accessable from rooftop or nearby antennas.
- Privacy/encryption of transmitted signals.

The net result is that the communications technology of the 1982-1992 time frame will provide flexible and powerful features for providing useful services to a wide variety of subscribers. It behooves DCA to actively interact with commercial carriers and vendors to inflence the selection of standard features and services that are applicable to DoD communications needs in CONUS. This approach will reduce the cost of services to the government if standard commercial software/firmware packages are available which also satisfy the requirements of the government.

VI. PLANNING AND IMPLEMENTATION STRATEGY

1. INTRODUCTION

The dominant costs of the current AUTOVON configuration lie in the access line and backbone trunking charges as illustrated in section II (Figure II-2). Alternatives 5 and 6, despite the uncertainties discussed in section V, offer the most potential for cost reduction in these areas with Alternative 6 providing the greatest cost savings potential. The extensive use of satellite transmission with satellite terminals located at customer premises minimizes both access line and backbone costs. Alternative 5 provides lower access costs by locating switches at, or near, subscribers and by trading some of the access line cost for more economical long-haul backbone transmissions. The potential for savings in Alternative 3 depends on tariff reductions via utilization of shared resources and technology related cost reductions.

This section considers possible implementation strategies. Although the discussion favors an evolutionary strategy that allows for deferred decision-making and local optimization, this strategy should be carefully evaluated before the DCA embarks on such a course. The discussion of section VI is primarily concerned with the following:

- Key events that impact AUTOVON.
- Decision-making considerations for implementation.
- The environment in which the next generation CONUS AUTOVON will be implemented.

2. MAJOR EVENTS AFFECTING THE NEXT GENERATION CONUS AUTOVON

This report (TR 18-78) was prepared as a supporting document for a publication to be issued by the DCA in May 1979 entitled "The DCS Plan FY 82-92." The strategies for implementation that could be achieved in this planning time frame are discussed. The pertinent major events affecting the next generation CONUS AUTOVON are depicted in Figure VI-1.

a. Key Events in the Commercial World. Across the top horizontal row are the events described in section III. These include the rapid implementation of the No. 4 ESS machines by the AT&T, which began in January 1976. The entry of digital PBX's and end offices into the same time frame is also depicted. Although the AT&T and BTL are now committed to developing the No. 5 ESS for end offices, note that the Bell System

alone has 10,000 end offices and that there are 15,000 office codes in the United States. These numbers indicate that the conversion of end offices to digital operation will be a very lengthy process when compared to the conversion of long distance dialing tandem offices to digital operation with the No. 4 ESS machine.

The launches of the Satellite Business System's (SBS) 12-14 GHz satellites and Western Union's Advanced WESTAR are shown as occurring in 1980 although some slippages should be expected. These satellites will be launched via NASA's space shuttles which have recently suffered a 6 month slippage.

The AT&T's advanced COMSTAR is tentatively scheduled for 1983. Nevertheless, despite delays, it would be reasonable to assume that small commercial satellite terminals operating in the 12-14 GHz range will be generally available in the mid-to-late 1980's.

b. Key Events in CONUS AUTOVON. The next horizontal row of events depicts pertinent events with respect to CONUS AUTOVON itself. The DCA has decided to close six AUTOVON switches by October 1979. Furthermore, the AUTOVON switch at Fairview, Kansas, is being considered for conversion to digital operation.

TR 18-78 is shown as being completed on schedule in 1978. The event shown as "VON Advisory Council" is postulated because of considerations discussed in section VI-3. The environment in which the next generation CONUS AUTOVON is being implemented is quite different from the one in which the current AUTOVON was implemented, and this TR recommends seeking external expertise via a mechanism called the AUTOVON Advisory Council. Furthermore, the technical expertise of the carriers should be tapped for critical review of DCEC's work relevant to its planning and to make appropriate recommendations. This event is labeled "Studies by Carriers" on Figure VI-1.

A conscious decision should be made no later than 1980 as to the course of action to be followed for the future CONUS AUTOVON based on the DCEC TR 18-78 as modified by subsequent analysis and commercial developments. The decision tree labeled "Continue Present Network," "Establish VON II Program," and "Evolutionary Approach" is amplified in section VI-3.

c. Key Events in AUTODIN and Secure Voice. The last horizontal row of events illustrated in Figure VI-1 shows other DCS implementations occurring during the decade of interest. They indicate that later in the decade, AUTOVON could serve as an automatic patching facility for "nailing up" time slots to provide economical trunking service to both

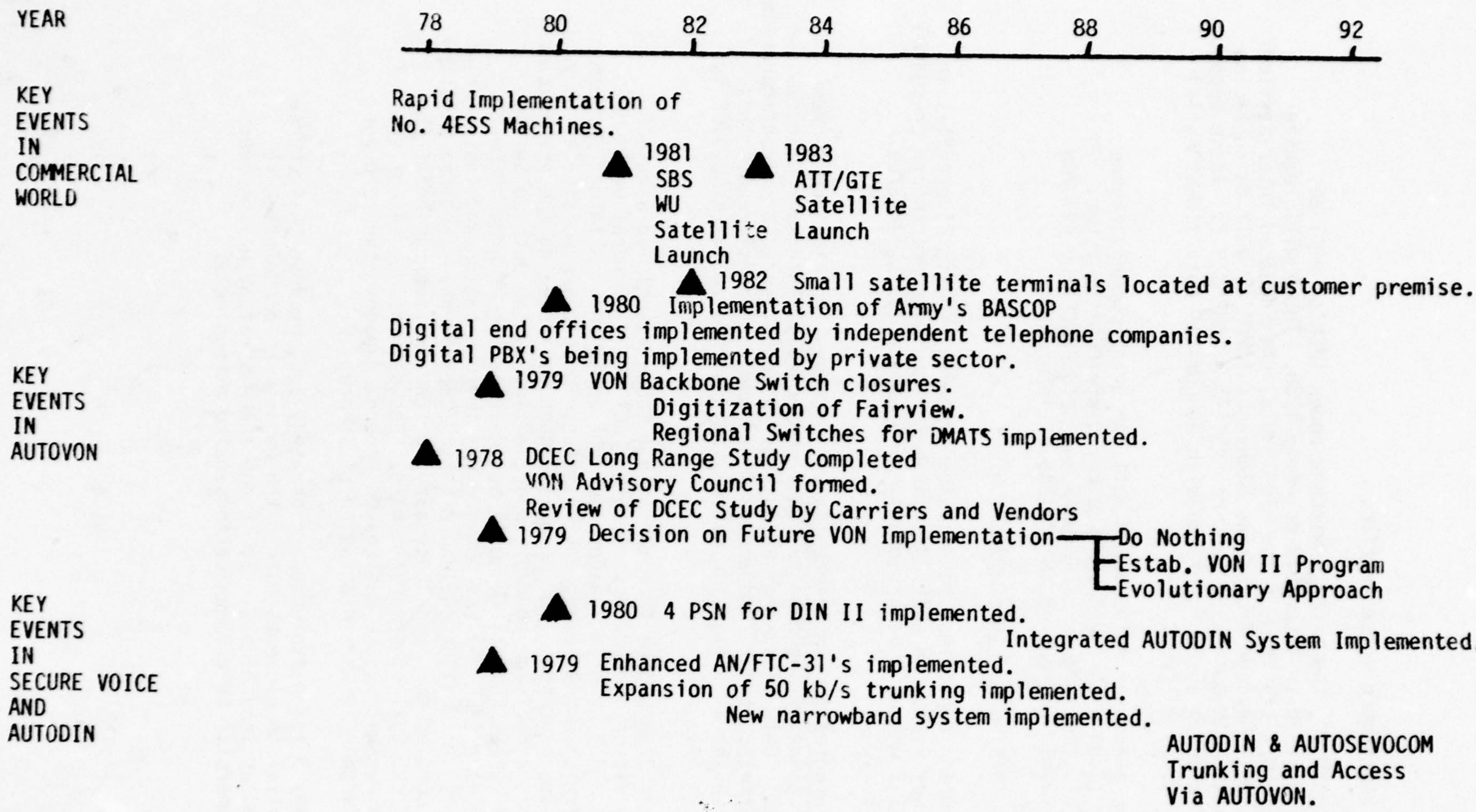

Figure VI-1. Major Events Relevant to the Next Generation CONUS AUTOVON in the Time Frame Up to 1992

AUTODIN II and Secure Voice traffic.

In AUTODIN II, the packet switched nodes (PSN's) will be initially activated in late 1979 or early 1980. These will require dedicated 56 kb/s trunks. In the mid-1980's, the Enhanced Inter-Service/Agency Automatic Message Processing Exchanges (AMPE's) will be replacing the current AUTODIN Switching Centers (ASC's) of AUTODIN I. These access lines could eventually be furnished with economical data lines "nailed up" by the future AUTOVON.

Current plans for AUTOSEVOCOM call for a narrowband service utilizing AUTOVON with the BELLFIELD key distribution system. This figure depicts the support of AUTODIN and AUTOSEVOCOM by AUTOVON occurring towards the end of the decade of interest.

3. DECISION-MAKING FOR IMPLEMENTATION

This section amplifies the decision tree depicted in Figure VI-1 in the row on Key Events in AUTOVON. The major decision points are presented in Figure VI-2 where three alternative implementation strategies are identified.

a. Strategies for Implementation. Strategy 1 retains the current AUTOVON structure of backbone switches connected by interswitch trunks and access lines. Only minor changes such as switch closures or reconfiguration of the interswitch trunks and access lines would be considered. This strategy needs no amplification since everyone involved with AUTOVON is familiar with it.

Strategy 2 should be familiar to all those associated with DoD system acquisition procedures. A formal AUTOVON II Program would be established and a Program Manager would be appointed. A formal program established within the Department of Defense must be responsive to many administrative processes and approval sequences including the preparation of a charter, a decision concept paper, review by the Defense System Acquisition Review Council (DSARC), and development of a Management Engineering Plan (MEP) by the DCA and the Implementation and Installation Plan (IIP) by the designated lead Military Department. The lead Military Department obtains the funds necessary for the implementation of the program and eventual contractual award. Because the details of the program are managed by the designated Program Manager, they are not addressed further in this discussion of Strategy 2.

Strategy 3 is an evolutionary strategy and, because this course is not familiar to elements within the Department of Defense, it is discussed at length here. It is not a new strategy having been used in commercial telecommunications quite extensively.

YEAR 78 80 82 84 86 88 90 92

DCEC study completed.
VON Advisory Council review completed.
Review by carriers and vendors completed.

Strategy 1: Retain present AUTOVON configuration and management structure.

Strategy 2: Define AUTOVON II Target System and proceed with process normal to systems acquisition in the Department of Defense.

Strategy 3: Follow evolutionary approach similar to the commercial telecommunications process.

1979 Issuance of Consolidated Guidance (CG) by DoD with respect to digital switching and transmission on posts, camps and stations.

1979 Exploratory arrangements with AT&T on interconnection with No. 4ESS including new tariff arrangements.

1980 Pilot projects for VON/No. 4ESS interconnection. If successful, proceed with full scale implementation.

1982 Pilot project with small satellite terminals. If successful, proceed with full scale implementation.

1985 Pilot project on digital interconnects between digital PBX's and central offices with satellite terminals. If successful, proceed with full implementation.

Figure VI-2. Strategies for Implementation for the Next Generation CONUS AUTOVON

The disadvantages of this approach are discused first to provide balance to the extensive consideration given to its advantages. This strategy may be characterized as being evolutionary and allows for local optimization. Any new change is not permitted to disrupt the existing system.

The disadvantages are:

- Lack of a precise target system in contrast to Strategy 2. As a result, there would be a lack of centralized control over the details of implementation.

- Lack of identification and control of a portion of the total funding and resource requirements for implementation.

- Loss of optimization of the new system because the existing systems must always be accommodated.

- Lack of standardization of hardware, thus sacrificing some economy of scale.

These disadvantages would be intolerable in the acquisition of a new weapons system in the DoD. But, with respect to telecommunications within the United States, there are many advantages:

- Flexibility to changes introduced by new technologies not foreseen in the original target system.

- Decision-making with local control of funds, for local needs, in line with the local environment.

- Minimum disruption to the existing systems and ongoing programs whose respective target systems (such as AUTODIN II) do not conform to the new target system (such as AUTOVON II).

Because Strategy 3 lacks a precise target system, in its place major desirable attributes of the future system are specified in light of the known certainties as of 1978. These attributes are described in detail in Appendix F and are summarized in section V-4.

Because of moderate technical risks identified in the course of the DCEC study with respect to the system attributes, RDT&E expenditures

should be authorized for the following areas:

- Dynamic stability, timing, synchronization, and bit count integrity in digital elements of AUTOVON, particularly at the interface of PBX's to the end offices of the Independent telephone companies and AT&T.

- Firmware and software interfaces between PBX's and collocated commercial satellite terminals.

- Firmware and software interfaces required for the DCA to exercise operational direction and management control.

- Special line interfaces for subscriber with multiple data speeds and digital secure voice operating at bit rates below 56 kb/s.

b. A Possible Scenario For An Evolutionary Strategy. In an evolutionary strategy, decision-making is dispersed and deferred until uncertainties are cleared rather than centralized and cast in the target system. Hence, it would be difficult to create the complete decision tree for this strategy. Nevertheless, for clarification, an example of a possible scenario is provided. Figures VI-3, 4, 5, and 6 illustrate the strategy in graphic form.

Figure VI-3 depicts the AUTOVON as it exists today; the backbone switches are represented by large crossed squares interconnected by lines representing voice channels for interswitch trunks.

The small crossed squares represent PBX's (base central offices) which provide AUTOVON access to two-wire stations. The rectangles labeled "A" represent the hardware interface specified by the DCS AUTOVON Interface Criteria for AUTOVON. AUTOVON 4-wire users who enjoy the benefits of MLPP are depicted by triangles under concave arcs labeled "VON 4W." The little squares labeled "A" depict the hardware interface for this subscriber. The lines represent voice channels dedicated via paired cable or a voice channel on FDM carrier equipment.

Note that (1) the precedent is well-established for specifying DCA criteria for elements within the confines of a post, camp, or station if associated with DCS services, and (2) the precedent is already established for AUTOVON providing trunking services for AUTOSEVOCOM and AUTODIN I.

Figure VI-4 depicts AUTOVON as it might appear in 1982. The disappearance of the large crossed square in the upper left of the

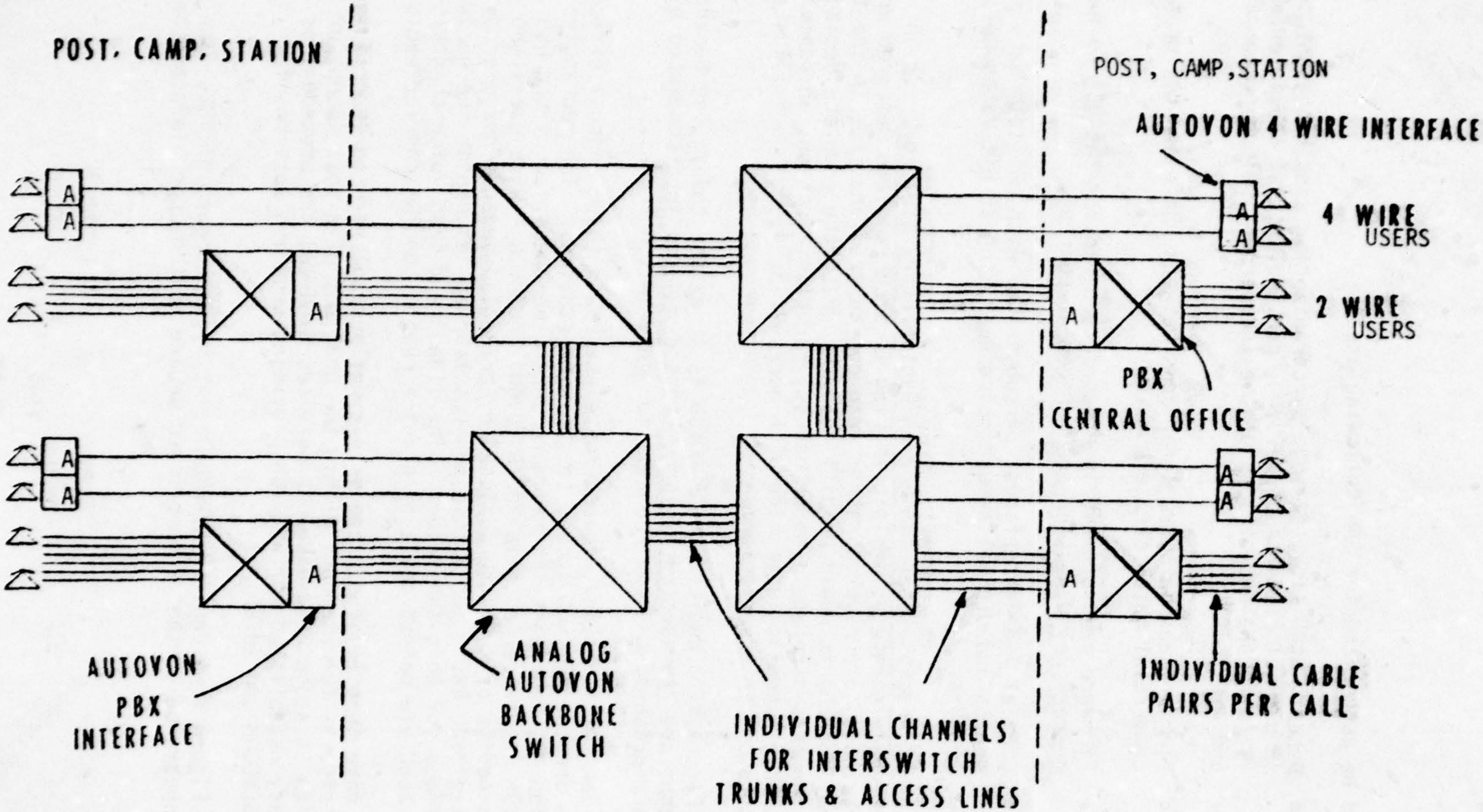

Figure VI-3. CONUS AUTOVON in 1978

AUTOVON backbone indicates the closure of six AUTOVON switches and the inclusion of at least one digital AUTOVON switch. At the lower right, note the change to a digital PBX with remote switching units. The crossed boxes and rectangles are labeled "D" to indicate digital switching units. The dashed line represents a T1 digitally multiplexed line, in contrast to solid lines which represent unmultiplexed voice channels on paired cables.

If feasible, experiments could be performed to link the AUTOVON switches to the Bell System's No.4 ESS on a trial basis. For example, AUTOVON switches in the Washington, D.C., area and the San Diego area could be linked to a No. 4 ESS to provide an alternate path to the AUTOVON polygrid. Should studies or trials performed at that time prove the scheme unworkable, the project would be abandoned. This is an example of deferred decision-making. Instead of deciding to interconnect AUTOVON switches to No. 4 ESS switches in 1978, the decision is deferred to 1982 or later when the uncertainties of 1978 are reduced.

Other trials based on the Experimental Integrated Switching Network (EISN) results, the availability of small satellite terminals, and satellites in the 12-14 GHz range could be made by 1984 with implementation by 1987 (Figure VI-5). A trial would be set up with perhaps two or four satellite terminals on post, camps, and stations on the east and west coasts to take advantage of low cost transcontinental services. If the trial were successful, this type of AUTOVON service would be increased. Note that all changes would be made without disrupting the existing services. Digital switches are completely compatible with the existing AUTOVON and they would be retained until the new techniques are clearly demonstrated. Additionally, experiments and trials with special interfaces for multi-rate data and secure voice can be conducted to establish interface criteria and standards for these special subscribers.

If these trial projects were to prove successful, then it might be possible to proceed to the configuration shown in Figure VI-6. This configuration represents a future AUTOVON wherein the majority of the digital switching functions are located on the posts, camps, and stations. The transmission media are provided by a mix-of-media established by survivability, technical, and economic considerations. Satellite earth terminals are collocated with central digital offices or AUTOVON switches and operate in a demand assigned mode with a 12/14 GHz satellite. A number of value-added benefits for satellite service are noted in the figures. Capabilities also exist for calls to traverse the DDD network, to be connected via 1.544 Mb/s lines to other nearby central offices, and to be routed to other AUTOVON switches. However, in all likelihood, by 1992 the attributes of a desirable future system will have changed because of new technologies, and the system will bear no resemblance to

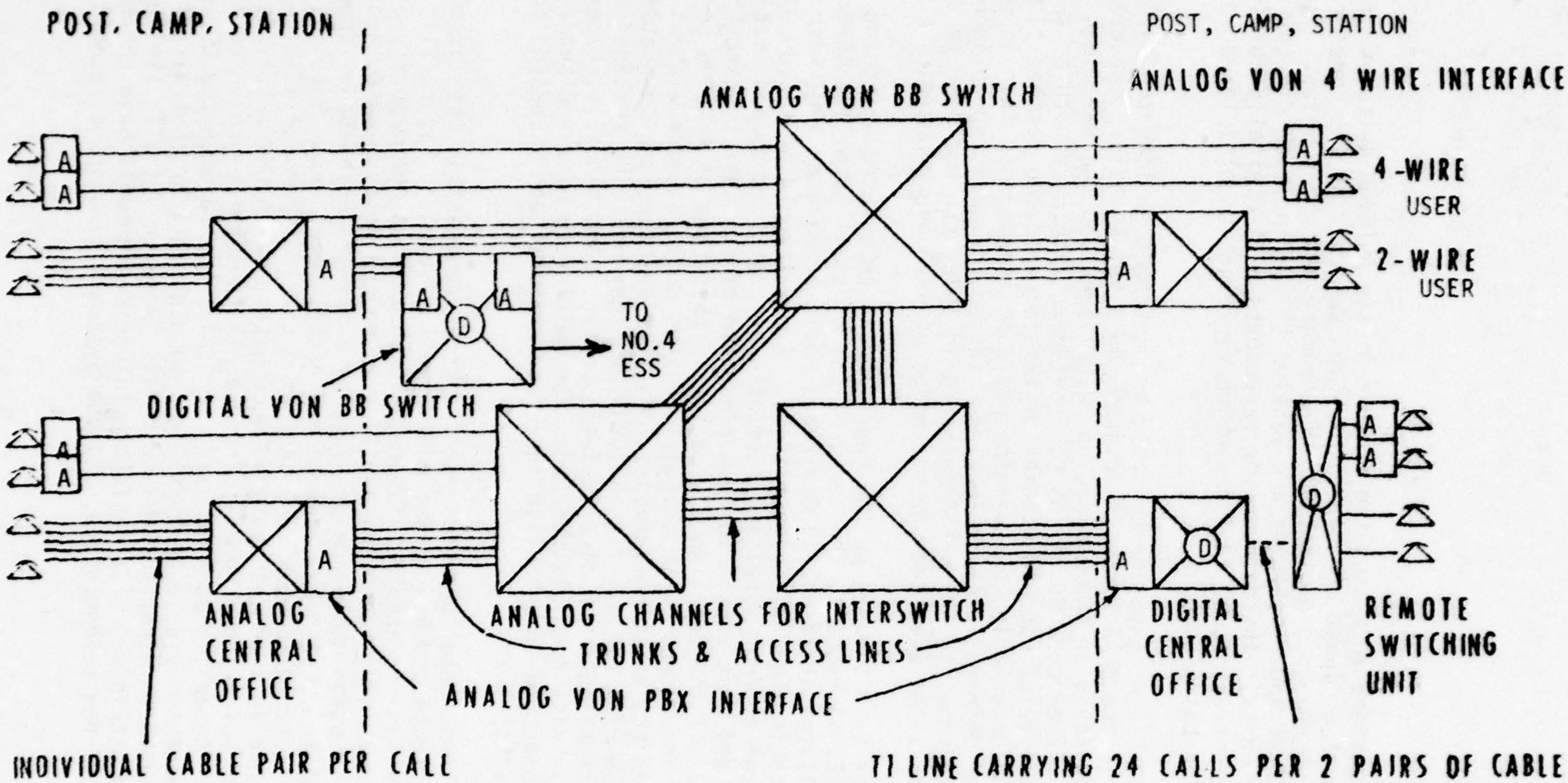

Figure VI-4. CONUS AUTOVON in 1982

Figure VI-6. Nevertheless, some of the projects along the way may yield the payoff of reducing AUTOVON costs and making AUTOVON more responsive. In this sense, Figure VI-6 does not represent a target system. Yet the desired attributes have led to trials and projects which may yield a high payoff while minimizing the risks of implementation.

The decisions as to when local posts, camps, and stations wish to convert to digital operation will depend on their local environments. This decision process exemplifies the evolutionary strategy.

Because integrated digital switching and transmission on posts, camps, and stations offers such great potential for protecting the overall systems and opens many options for the future while remaining completely compatible with the current AUTOVON, it is recommended that the Department of Defense issue the following guidance in the next issuance of the Consolidated Guidance (CG):

"Wherever the communications plants of posts, camps, and stations including central offices, PBX's, and cable plant, are in need of upgrading due to obsolescence or changing and growing needs, the Military Departments should accomplish such upgrades with a common uniform strategy utilizing the U.S. commercial T1 carrier technology and T1 compatible switching technology. In considering cost tradeoffs for upgrading these facilities, life cycle costing of both transmission and switching must be addressed as opposed to the central offices exclusively. Use of the two technologies should be integrated to allow opportunities to eliminate channel banks, voice frequency patching, monitoring, and terminating facilities except for interfacing with analog systems.

The digital switches should provide for least cost routing of off-post communications, automatic message accounting, and software or firmware which is electronically alterable economically for future changes in requirements. This guidance applies to upgrading leased as well as Government-owned facilities."

The reasons for recommending this guidance are:

- Economy of operation or leasing of post, camp, and station telecommunications, and ease of providing new features that may be needed in the 1980's.

- Potential for future savings with the next generation CONUS AUTOVON while remaining compatible with the present AUTOVON.

- Potential for providing economical, dedicated, nailed-up services to AUTODIN, Secure Voice, and Special Purpose Users.

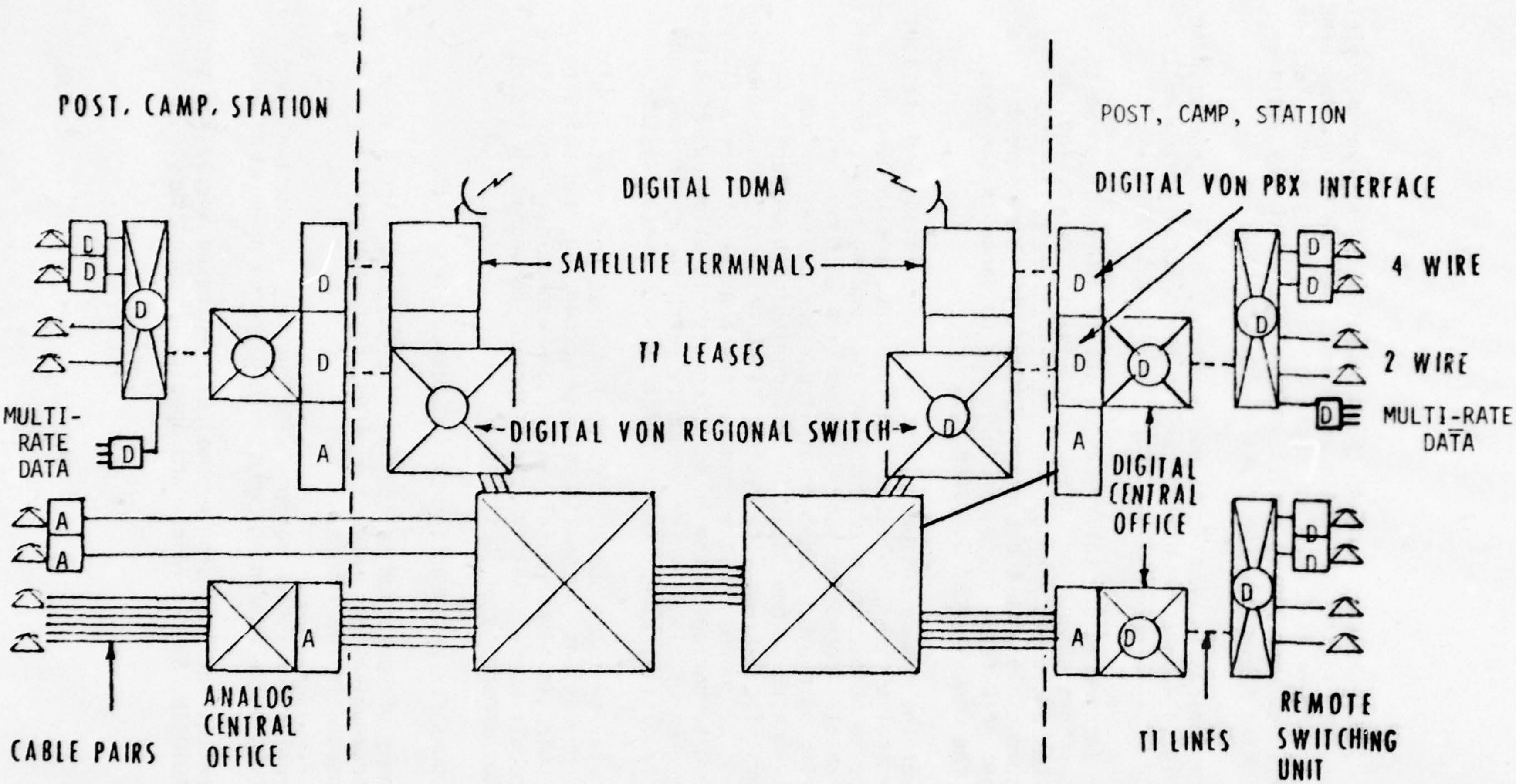

Figure VI-5. CONUS AUTOVON in 1987

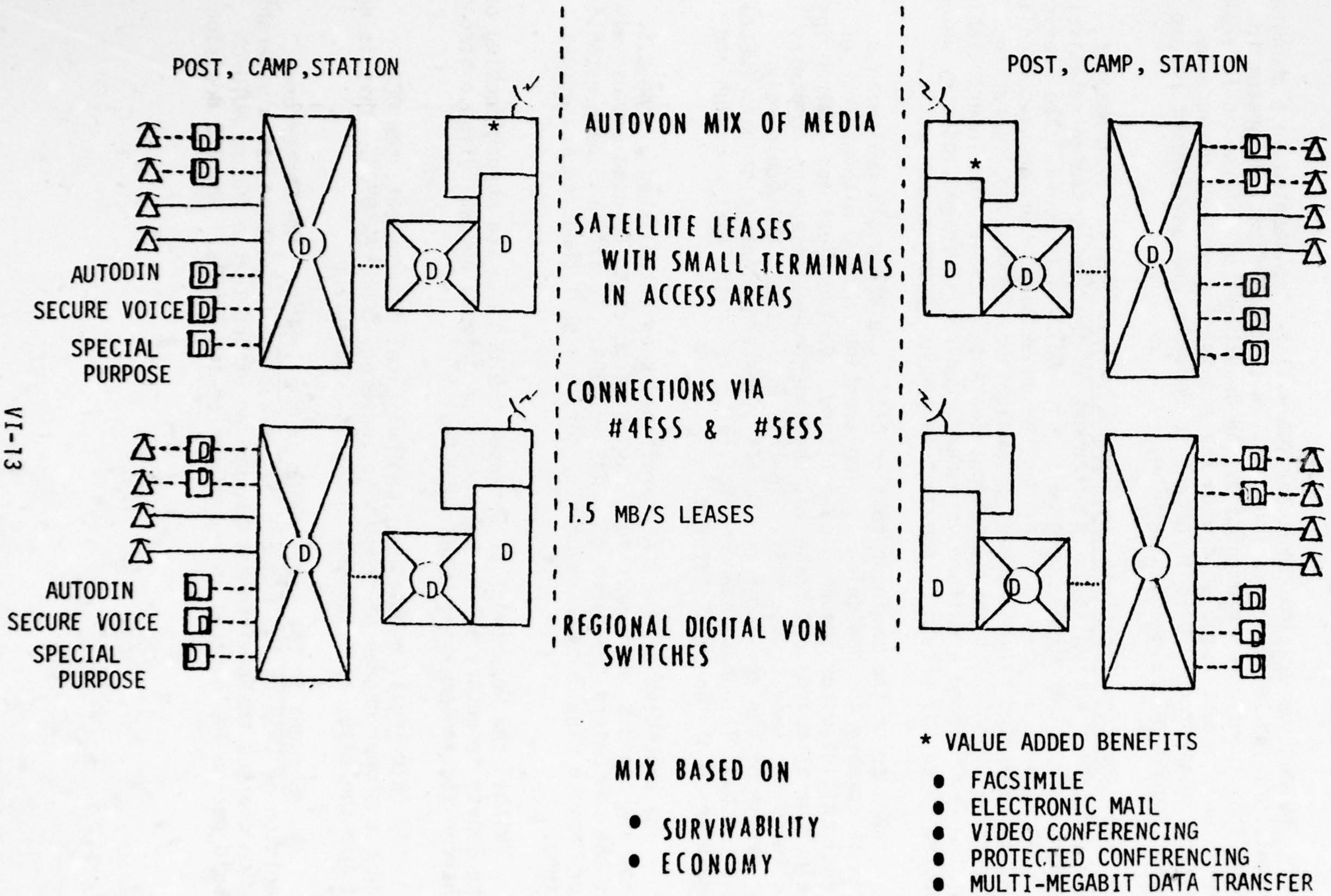

Figure VI-6. CONUS AUTOVON in 1992

- Ease of providing increased protection or encryption of these facilities economically in the future.

4. THE IMPLEMENTATION ENVIRONMENT

The next generation CONUS AUTOVON will be implemented in a changing regulatory and political environment. A telecommunications system in the CONUS cannot be implemented by the Department of Defense unilaterally in an environment associated with the acquisition of a major weapons system. Therefore, it is important to consider the environment before embarking on an implementation plan.

a. The Communications Environment in the 1960's. By hindsight, the regulatory and political environment in the 1960's seemed relatively simple for implementing a program such as AUTOVON in CONUS. The American Telephone and Telegraph Company was the unquestioned and quasi-monopolistic leader regulated by the Federal Communications Commission, operating under the umbrella of the Communications Act of 1934. The interpretations of the law favored a uniform, standard, centrally managed industry which had fostered the growth of the best telephone system in the world.

Because of the dominant role of AT&T, the DCA could deal with a single company for designing and implementing AUTOVON without fear of legal criticism for ignoring competitors. On technical and engineering telephone standards and criteria, the Independent telephone companies followed the lead of the AT&T. In this environment DCA could rely primarily on the resources of the AT&T, Western Electric Company (WECo), and the Bell Telephone Laboratories (BTL) to do the system design and engineering of the CONUS AUTOVON.

The precedent of the SCAN tariff had been established by the U.S. Army and the U.S. Air Force for leasing switches to be used exclusively by the DoD before the birth of CONUS AUTOVON. Tariffs had been established for Private Line Services necessary for long haul trunking and access lines.

Within the Department of Defense, the DCA had the strong backing of the Deputy Secretary of the Department of Defense and was given a strong charter for implementing CONUS AUTOVON.

In this legal, regulatory, and political environment, the DCA had the proper degree of freedom to implement CONUS AUTOVON. This is no longer the case, as discussed in the next paragraph.

b. Changes in the Environment in the 1980's. The Carterfone decision of 1968 by the Federal Communications Commission was a watershed which changed the environment to such an extent that a future AUTOVON could not be implemented in the manner of the 1960's. The FCC decision

essentially made the American telephone network available to non-Bell supplied communications equipment, first in the arena of user stations, and subsequently even in the arena of private branch exchanges.

In 1972, the FCC authorized the common carriers to construct and operate satellite systems for domestic telecommunications in the "free enterprise" mode as opposed to the regulatory mode, thus opening another dimension for implementing the future AUTOVON. The AT&T was prohibited from furnishing private line services via satellite for three years, although this restriction of service does not extend to the U.S. Government.

Because of these developments, the Consumer Communications Reform Act of 1934 is being considered for revision by Congress. With the central issue of regulated monopoly vs. free competition at stake, it is difficult to predict when such a resolution, if ever, will be forthcoming.

c. Implications to the Future AUTOVON. Some of the more advanced PBX's which might be used for posts, camps, and stations are available from non-Bell vendors. Within the telephone industry itself, non-Bell vendors are marketing digital end offices. Finally, non-Bell carriers are marketing new satellite services.

The DCA, then, faces a new world where AT&T is not the sole arbiter of telephone industry standards and criteria in the design of a new AUTOVON, and where agreements made with vendors and carriers are open to regulatory and legal challenges before the FCC and the courts. In the technical arena, for example, the new satellite carriers have ignored the cautionary and expert advice of AT&T specialists who predicted dire consequences in the performance of telephone services because of absolute delays and echoes resulting from satellite transmission.

The Independent telephone companies have ignored the advice of AT&T regarding the pitfalls of loop plant interfaces with digital end offices. The DCA, in implementing a new AUTOVON, will face conflicting technical advice in the new environment, making technical decision-making difficult.

Even worse than this conflicting advice is the spectre of commitments involving millions of dollars being rendered illegal by the courts, exemplified by the decision of a Court of Appeals on Satellite Business Systems.

It should be apparent, then, that a number of major issues transcend the jurisdiction of the Department of Defense and are not at all similar to issues requiring resolution in the acquisition of a

weapons system. Issues that must be addressed include the following:

- What legal and regulatory changes will inhibit or foster the implementation of a future CONUS AUTOVON?
- What are the effective mechanisms to resolve conflicts between the technical advice of Independents and Special Carriers and the technical advice of AT&T?
- What changes must be made to the DoD system acquisition processes to make them applicable to implementing the Future CONUS AUTOVON?

Because of these uncertainties, it is recommended that the Director, DCA, consult with external experts in telecommunications matters with expertise in the following areas:

- Technical and engineering aspects of the design and implementation of telecommunications systems.
- Regulatory, legal, and legislative matters.
- Implementation of systems within the DoD which are not weapons systems.

VII. SIGNIFICANT FINDINGS AND CONCLUSIONS

This section summarizes the significant findings and conclusions of the seminars, studies, and analyses conducted by DCEC with respect to system design concepts for the next generation CONUS AUTOVON. The discussion is organized in terms of (1) significant findings, and (2) recommendations.

1. SIGNIFICANT FINDINGS

On the basis of a survey of developments in commercial telecommunications discussed in section III of this Technical Report, the following possibilities are considered significant:

- Rapid implementation of the digital No. 4 ESS in the United States by the Bell System and Independent Telephone Companies as part of a gradual evolution from the Switched Analog Network (SAN) to the Switched Digital Network (SDN). It is anticipated that 87 No. 4 ESS's will be operating by 1982 with 12 to 15 per year being added annually thereafter.

- A growing availability of economical commercial digital private branch exchanges (PBX), and Class 4/5 offices with remote switching units, compatible with commercial T1 digital lines which makes it possible to place network "intelligence" (e.g., routing and control) at levels closer to the user, instead of embedding it in the backbone structure.

- Availability in the early 1980's of small commercial satellite terminals which may be located close to user premises, offering the potential to reduce access line and interswitch trunk charges.

On the basis of the analysis of three design approaches and six alternatives discussed in section V of this Technical Report, the following findings are considered significant:

- From an overall system point of view, further switch closures in the present AUTOVON may not be preferred because the penalty in survivability is large compared to a small benefit in reduced charges. There are probably exceptions to this general statement where specific survivability aspects will have to be carefully considered on a switch by switch basis.

- A future CONUS AUTOVON which incorporates many switches, or appears to have many switches (virtual AUTOVON), and utilizes economical and diversified transmission could have significant survivability advantages.

- New network configurations based on advanced concepts have a ten-year life cycle cost advantage over continuing with the present approach.

- Basic changes in tariff structures must take place in order to take further advantage of the advancing technology, especially in transmission.

- Uncertainties in Telephone Company future services and tariffs have clouded the analysis of these applications to the next generation AUTOVON in CONUS. Because of the inherent economies of scale in the public toll network, options should be left open to reevaluate this area as uncertainties diminish.

- The DCS CONUS AUTOVON should rely heavily on the common carrier grid.

- Communications resources do not have to be more survivable than the users.

- It is not practical to design DCS facilities to withstand blast from direct nuclear attack.

- Collateral blast damage avoidance should be a factor in locating switches.

- Alternative 5 exhibits the best performance for the postulated switch damage scenario.

- Alternative 6 provides a graceful degradation of performance compared to Alternatives 1 and 2.

- A mix of alternatives configured to support the total traffic load may also provide graceful degradation properties.

- Private line (i.e., dedicated trunking and switching) digital switched network alternatives provide the least-cost implementation of CONUS AUTOVON based on current tariffs.

- A distributed network with on-base switches is preferable from a network survivability point of view due to the large number of switches.

- Local communications optimization at the Base/Facility level could have a favorable cost impact on CONUS AUTOVON.

2. RECOMMENDATIONS

On the basis of findings noted above and explored in greater detail in the text and appendixes, three categories of recommendations are discussed below. These include recommendations in the areas of management, system engineering, and RDT&E.

a. Management Related Issues. DCA needs consultation with external experts in telecommunications matters with expertise in the following areas:

- Common carrier planning for the design and implementation of new telecommunications systems and services.

- National telecommunications policy formulation, regulatory, legal, and legislative matters.

- DoD acquisition policy changes to avoid adherence to irrelevant weapons systems based procurement practices.

DCA should make a decision about the course of action before the publication of the DCS Ten Year Plan FY 84-94. The alternative strategies are:

- Retain the basic structure of CONUS AUTOVON, probably incurring significant cost growth.

- Establish a Target System and organize an AUTOVON II program office for managing the system acquisition, requiring a DSARC procedure.

- Establish an evolutionary, opportunistic strategy exploiting developments in commercial telecommunications. On the basis of the DCEC study, this alternative is the preferred one.

If the DCA approves the preferred evolutionary acquisition strategy recommended by DCEC, the following additional recommendations should be considered:

- In view of the almost certain rapid implementation of the No. 4 ESS (87 by 1982), begin developmental inquiries with commercial carriers which may lead to studies and pilot programs cost reduction. Proceed with full implementation if the pilots are successful.

- In view of the possibilities of the availability of small satellite terminals in the early 1980's, begin exploratory studies with commercial satellite carriers who may offer such services.

- In view of the great potentials offered by digital PBX's and end offices, the Department of Defense should issue the guidance in its next Consolidated Guidance spelled out in detail in section VI (page 11) of this report.

b. System Engineering Issues. The major technological developments and system issues that should be explored include:

- Deployment of digital PBX's capable of serving both voice and data requirements and which are compatible with U.S. commercial T-1 digital services, thus placing network "intelligence (e.g., routing and control) at the local level vice imbedding it in the backbone structure.

- Direct connection of such PBX's to the digital end offices existing at the lower-end of the commercial hierarchy thereby reducing access line costs.

- Exploitation of the entire existing commercial facilities, thereby achieving a greater degree of survivability than now achievable.

- Exploitation of commercial satellite services, allowing economical satellite terminals to collocate with the digital PBX's, thereby reducing transmission charges.

- Determination of preferred routing techniques and common channel signaling system.

- Determination of preferred mix of terrestrial private line switched network, satellite service, and DDD services based on reduced cost and increased survivability.

- Exploitation of integrated voice/data techniques.

- Development of preferred system concepts in sufficient detail to force consideration of new tariff structures based on DoD requirements and operational needs.

- Flexibility to allow secure voice and AUTODIN services to be integrated into AUTOVON.

c. RDT&E Related Issues. Because of moderate technical risks identified in the course of the DCEC study, RDT&E expenditures should be authorized for the following:

- Development of functional standards for local PBX's to insure the incorporation of features needed for the future DCS.
- Investigation and development of software/firmware interface criteria between PBX's and collocated commercial satellite terminals.
- Investigation of dynamic stability, timing, synchronization, and bit count integrity in digital elements of AUTOVON, particularly at the interface of PBX's to the end offices of the Independents and AT&T.
- Development of firmware and software interface criteria required for the DCA to exercise operational direction and management control.
- System tests and pilot programs for preferred concepts and operational techniques associated with digital PBX's, local switches, backbone switches, and small satellite earth terminals.
- Investigation of new tariff offerings which can pass to the subscriber the technological advantages identified in this study.
- Investigation of special line interfaces for subscribers with multiple data speeds and digital secure voice operating at bit rates below 56 kb/s.

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GLOSSARY OF TERMS

AECo	Automatic Electric Co.
A-J	Anti-Jam. A device, method, system, or technique that reduces or eliminates the effects of jamming.
AM	Amplitude Modulation. Modulation in which the amplitude of the carrier-frequency current is varied above and below its normal value in accordance with the audio intelligence to be transmitted.
AMPE	Automated Message Processing Exchange. Generic term that includes the Army's Automated Multi-Media Exchange; the Navy's Local Digital Message Exchange and the Naval Communications Processing and Routing System; Air Force's Automated Telecommunications Program (now AFAMPE); and the NSA's STREAMLINER.
Analog Signal	A signal that varies in a continuous manner, such as voice or music. An analog signal may be constrasted with a digital signal which represents only discrete states.
ASC	AUTODIN Switching Center.
AT&T Co.	American Telephone and Telegraph Co.
AUTODIN	AUTOmatic DIgital Network. A worldwide communications system which provides message-switched narrative and data service for the DoD and certain non-DoD subscribers. It is part of the Defense Communications System (DCS) and shares the use of certain AUTOVON facilities.
AUTOSEVOCOM	AUTOmatic SEcure VOice COMmunications exists today as a worldwide network which provides encrypted voice communications among designated DoD and certain non-DoD subscribers. Future secure voice subscribers will be an integral part of CONUS AUTOVON and obtain encryption based upon the NSA work on the BELLFIELD family of equipment. It is part of the Defense Communications System (DCS).
AUTOVON	AUTOmatic VOice Network. A worldwide automatic communications system for end-to-end circuit-switched voice communications for the Department of Defense and certain non-Department of Defense subscribers. It is part of the Defense Communications System (DCS).

Balance Criterion	Communications will be in balance when the enemy cost to damage/disrupt communications is the same as the cost to eliminate users. This most commonly occurs when users and communications are located in the same target area.
BASCOP	BASe COmmunications Plan, which provides policy and guidance for all future upgrades of communications for U.S. Army bases.
BER	Bit Error Rate. The ratio of erroneous bits to total received bits in a digital transmission system.
b/s	Bits per Second. A rating that specifies the modulation rate of a digital transmission system.
BTL	Bell Telephone Laboratories, Inc.
Busy Hour	That hour during which the portion of the telephone network in question carries the most traffic. Traffic peaks caused by holidays or special events are not considered. Switching systems and trunk groups are normally sized for the busy hour.
Call Forwarding	One of the custom calling services. When call forwarding is activated by a customer, all calls to that line are automatically routed to another line designated during activation.
Call Waiting	The custom calling service that provides a tone burst to a customer on an established call when a second call has been directed to that line. The notification tone is heard only by the called customer, whereas the incoming caller hears regular audible ringing. The customer can place the existing call on hold, connect to the calling party, and then repeat the procedure to reestablish the original connection. The operation of changing the talking connection can be repeated indefinitely.
Carterfone Decision	A decision by the Federal Communications Commission in 1968 to the effect that telephone company customers should be permitted to connect their own equipment (e.g., data modems) to the public telephone network provided that this interconnection does not adversely affect the telephone companies'

operations or the utility of the telephone system to others. Prior to this decision, only telephone company provided equipment could be connected to the network.

CCIS	Bell System's Common Channel Interoffice Signaling. (See CCS also).
CCITT	International Telephone and Telegraph Consultative Committee. One of two committees that support the International Telecommunications Union (ITU) by conducting studies on technical and operating questions and recommending standards; the other is the International Radio Consultative Committee (CCIR). The ITU, a specialized agency of the United Nations, was created to encourage international cooperation in the development and use of communications by radio, telegraph, cable, telephone, and television.
CCS	Common Channel Signaling. A signaling system, developed for use between stored program switching systems, in which all of the signaling information for a group of trunks is transmitted over a dedicated high-speed data link, rather than on a per-trunk basis. CCS can reduce call setup time and save money compared with individual trunk signaling.
CCSA	Common-Control Switching Arrangement. A tariff arrangement in which switching for a private network is provided by one or more common-control switching systems. The switching systems may be shared by several private networks and also may be shared with the public telephone network.
Central Office	A switching system that connects lines to lines, lines to trunks, and trunks to trunks. The term is sometimes used loosely to refer to a telephone company building in which a switching system is located and to include other equipment (such as transmission system terminals) that may be located in the building. A Class 5 office serves as a network entry point for customers - called a local or end office switch. A Class 4 office is a next higher level in the toll hierarchy with tandem trunking capability. A Class 4/5 is a combination of both type offices, local and tandem.
Class 5 Office	See "Central Office" and "End Office."

Comstar	AT&T Co. domestic communications satellite.
CONUS	Continental United States. The 48 contiguous states.
CSN	Canadian Switched Network.
Cut Set Analysis	A graph theory technique used to determine flow (including zero flow) by severing links or nodes of a graph (network).
DAMA	Demand Assignment Multiple Access. (See Demand Assignment.)
DCA	Defense Communications Agency.
DCEC	Defense Communications Engineering Center.
DCS	Defense Communications System. The DCS is the composite of long-haul, point-to-point, and switched network telecommunications systems serving the DoD and certain other Government agencies.
DDD	Direct Distance Dialing Network. Strictly speaking, the telephone network over which a customer can dial all calls to which toll charges are applicable. Because of the widespread availability of DDD service and because exchange areas can be dialed directly using the same facilities, the term DDD is sometimes applied to the entire network that provides public telephone service.
DDS	Digital Data System. This is a Bell System offering of a nationwide private-line synchronous data communications network formed by interconnecting digital transmission facilities and providing special maintenance and testing capabilities. Customer channels operate at 2.4, 4.8, 9.6, or 1.544 kilobits per second.
DECCO	Defense Commercial Communications Office.
Demand Assignment	Technique that allows satellite transponder capacity to be dynamically shared by geographically dispersed earth terminals.
Digital Signal	A signal that has a limited number of discrete states prior to transmission. This may be contrasted with an analog signal which varies in a continuous manner and may be said to have an infinite number of states.

Digital Transmission	A mode of transmission in which all information to be transmitted is first converted to digital form and then transmitted as a serial stream of pulses. Any signal--voice, data, television--can be converted to digital form.
DIM	Data In the Middle.
DOCC	DCA Operations Control Complex.
DSARC	Defense Systems Acquisition Review Council.
DUV	Data Under Voice. An arrangement for transmitting 1.544 megabit-per-second data streams in the bandwidth available underneath the portion of the baseband used for voice channels on existing microwave systems.
EMP	Electro-Magnetic Pulse. The pulse of electro-magnetic radiation generated by a large nuclear explosion. Hardening of switching sites includes shielding to prevent pulses from interfering with communications and electronic equipment.
End Office	A local switching office where loops are terminated for purposes of interconnection to each other and to trunks. End offices are designated Class 5.
Erlang	A dimensionless unit of traffic intensity used to express the average nummber of calls under way or the average number of devices in use. One Erlang corresponds to the continuous occupancy of one traffic path. Traffic in Erlangs is the sum of the holding times of paths divided by the period of measurement. The term Erlang can be used to express the capacity of a system; for example, a trunk group of 30 trunks, which in a theoretical peak sense might carry 30 Erlangs of traffic, would have a typical capacity of perhaps 25 Erlangs averaged over an hour.
ESS	Electronic Switching Sytem. A class of modern switching systems in which the control functions are performed principally by electronic devices. There are two types in use: space division and time-division. The AT&T No. 1 ESS is a space division switch and the No. 4 ESS is a time-division switch.
ET	Earth Terminal (satellite).
EW	Electronic Warfare. Warfare directed at the electronic capabilities of an enemy to detect and prevent hostile use

	of the electromagnetic spectrum. Electronic warfare includes electronic countermeasures and counter-countermeasures.
FCC	Federal Communications Commission. A board of seven commissioners, appointed by the President of the United States under the Communications Act of 1934, having the power to regulate interstate and foreign communications originating in the United States by wire and radio.
FDC-7	Fully distributed cost method No. 7.
FDM	Frequency Division Multiplex serving a number of simultaneous calls by means of a common transmission path with a different frequency band for the transmission of each call.
FEC	Forward Error Correcting.
FED-6	Federal (standard) No. 6 signaling.
Firmware	A computer program or instruction used so often that it is stored in a read-only memory instead of being included in software. A *microprogram* is an example of firmware being somewhere between hardware and software in performance.
FTS	Federal Telecommunications System. The FTS consists of *two primary networks*, the FTS Voice Network and the Advanced Record Service (ARS) for record traffic. The FTS Voice Network provides long distance voice service to Federal Agencies of the U.S. Government in the 48 contiguous states, Alaska, Hawaii, and Puerto Rico.
GOS	Grade of Service. The proportion of calls, usually during the busy hour, that cannot be completed due to limits in the call-handling capability of a component in a network. For example, service objectives are defined on a per-link (per-trunk-group) basis for the last-choice groups in a traffic network.
GTE	General Telephone and Electronics.
HEMP	High Altitude Electro-Magnetic Pulse. (See EMP).
Independent Co.	A telephone company not affiliated with the Bell System and having its own "independent" territory. There were over

	1600 independent telephone companies in the United States in 1975.
Intercept	Covert reception, and the analysis of communications for intelligence purposes.
IST	Interswitch Trunk. A message circuit between two points, both of which are switching centers and/or individual message distribution points.
JCSAN	Joint Chiefs of Staff Alerting Network.
JSS	Joint Surveillance System (successor to SAGE).
kb/s	Kilobits per second. One thousand bits per second, used in specifying the modulation rate of a digital transmission system.
Least Cost Routing	Routing control by resident firmware and software at a local central office, designed to minimize cost.
Local Office	A switching system that performs end office (Class 5 office) functions. See, also, Central Office.
LOS	Line of Sight, usually refering to LOS microwave radio transmission.
LSI	Large Scale Integration (circuit elements). The construction of well over 100 interconnected equivalent gate circuits (or other circuits of similar complexity) on a single integrated chip to form a major system function or act as a major subsystem.
MEECN	Minimum Essential Emergency Communications Network.
MF	Multifrequency pulsing/signaling. An inband interoffice address signaling method in which ten decimal digits and five auxiliary signals are each represented by selecting two frequencies out of the following group: 700, 900, 1100, 1300, 1500, and 1700 Hz.
MLPP	Multi-Level Precedence Preemption.
MPL	Multi-Schedule Private Line (tariff).
MTS	Message Telecommunications Service. Service that uses in whole or in part the public telephone network. Examples include public telephone service, mobile radio-telephone service, air-to-ground service, etc. Private-line services are not included.

Multiplex	The process or equipment for combining a number of individual channels into a common spectrum or into a common bit stream for transmission.
NCA	National Command Authorities. The NCA consists only of the President and the Secretary of Defense or their duly deputized alternates or successors.
Network Management	A set of procedures, equipment, and operations designed to keep a traffic network (AUTOVON, for example) operating near maximum efficiency when unusual loads or equipment failures would otherwise force the network into a congested, inefficient state.
NI	Net Investment.
NOE	Net Operating Earnings.
NORAD	North American Air Defense Command.
NSA	National Security Agency.
Operational Network	A network, utilized in this study, serving subscribers who have missions highly related to national security and whose requirements, it was felt, could not be met solely within the shared, non-dedicated trunking such as the commercial switched system.
PAM	Pulse Amplitude Modulation. A modulation technique in which the amplitude of each pulse is related to the amplitude of an analog signal. It is used, for example, in time-division multiplex arrangements in which successive pulses represent samples from the individual voiceband channels; also used in time-division switching systems of small and moderate size.
PBX	Private Branch Exchange. A private switching system, either manual or dial, usually serving a post, camp, station, or a government agency and usually located on the customer's premises. Telephones served by the PBX are called stations. Calls from one station to another may be handled manually or automatically depending on the type of PBX. Calls between stations and an external network, for example the public telephone network, may be automatic or handled manually by the PBX attendant. Direct inward dialing and automatic identified

outward dialing service can be provided by some PBX's. Tie trunks between PBX systems of a single customer are commonly used.

PCM	Pulse Code Modulation. Conversion of an analog signal, such as voice, to a digital format, ordinarily in terms of binary-coded pulses representing the quantized amplitude samples of the analog signal.
Polygrid	Routing procedure used in the present CONUS AUTOVON wherein each switching center is of equal rank, as contrasted to a hierarchical ranking utilized in the commercial network.
PPBS	Planning, Programming, Budgeting System.
PSN	Packet Switched Node, as used in the Integrated AUTODIN.
RDT&E	Research, Development, Test, and Evaluation.
RSU	Remote Switching Unit.
SAFEGUARD	Program name for the Army Antiballistic Missile Program installed in North Dakota.
SAGE	Semi-Automatic Ground Environment.
SBS	Satellite Business Systems.
SCAN	Switched Circuit Automatic Network. A tariff arrangement by AT&T providing interstate private line services for two U.S. Government agencies -- the Department of Defense and the General Services Administration.
SF	Single Frequency. An ac method of conveying dial-pulse and supervisory signals from one end of a trunk or line to the other, using the absence or presence of a single specified frequency. A 2600 Hz tone is used in AUTOVON today.
SPC	Stored Program Control. A switching system central control with an electrically alterable memory which provides the mechanism to change translation information readily.
SSB-AM	Single Side Band -- Amplitude Modulation. A

communications technique in which one of the two sidebands for amplitude modulation is suppressed.

STP — Signal Transfer Point. In the Bell System CCIS, a message switching system that permits signaling messages to be sent from one switching system to another by way of one or more other offices at which STPs are located. It is part of a non-associated signaling system and it reduces the number of CCIS data links required to serve a network.

T1 Carrier — A completely transistorized 24 channel PCM system designed to provide an economical facility for short-haul trunks, primarily in large metropolitan areas. In the T1 carrier equipment, 24 voice channels are combined into a single pulse amplitude modulated (PAM) wave by time division multiplexing (TDM). The sampling rate for each channel is 8000 samples per second. The PAM signal is compressed and encoded into a pulse code modulated (PCM) signal for transmission over the line. A seven digit code is used to represent each PAM. The signal to be transmitted over the repeatered line consists of a train of pulses. The pulse position repetition rate is 1.544-megabits per second.

T1C — A digital line design, which utilizes techniques similar to T1 and provides transmission at a 3.152-megabit-per-second rate.

Tariff — The published schedule of rates, regulations, and descriptions governing the provision of communications services. Tariffs are filed with the appropriate regulatory agency.

TCF — Technical Control Facility. That element of a communications network with the necessary physical, electrical, and human resources to provide technical control, to interface transmission and switching elements of the system, and to interface special purpose networks and users.

TDMA — Time Division Multiple Access. A digital method of modulating signals, usually combined with pulse code or delta modulation and phase-shift keying.

TELCO — Telephone Company (Bell System, General System or Independent CONUS).

TELPAK — Package services offered by AT&T and Western Union, making available bulk facilities for a fixed charge.

Time Division	A method of serving a number of simultaneous channels over a common transmission path by assigning the transmission path sequentially to the various channels, each assignment being for a discrete time interval.
Toll Switch	A switching center where trunks are interconnected to serve toll calls. Toll offices are arranged in a hierarchical structure.
Transmission Facility	An element of physical telephone plant that performs the function of transmission; for example, a multipair cable, a coaxial cable system, or a microwave radio system.
Traveling Class Mark	A unique "label" that identifies a call as it is routed through the network; e.g., an indication that the call originated from AUTOVON. Traveling class marks will be possible with CCS. It will be possible to use the same transmission facility in several different traffic networks, each identified by a traveling class mark.
WATS	Wide Area Telecommunications Service. WATS permits customers to make (OUTWATS) or receive (INWATS) long distance voice and to have them billed on a bulk rather than individual call basis. The service is provided within selected service areas, or bands, by means of special private-access lines connected to the public telephone network via WATS-equipped central offices. A single access line permits inward or outward service, but not both. (Alternative 4 in this study utilizes OUTWATS.)
WECo	Western Electric Co.
Westar	Western Union domestic communications satellite.
WWMCCS	Worldwide Military Command and Control System. Provides the means for operational direction and technical administrative support involved in the function of command and control of U.S. Military Forces.

APPENDIX A

AUTOVON II REQUIREMENTS

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	A-1
II.	CONUS AUTOVON	A-4
III.	SECURE VOICE SUBSCRIBERS AND THEIR INTERFACE WITH THE FUTURE AUTOVON II	A-11
IV.	SPECIAL PURPOSE USERS AS POTENTIAL CANDIDATES FOR AUTOVON II	A-13
V.	VOICE USER CAPABILITY OBJECTIVES	A-17
VI.	SUMMARY	A-18
	REFERENCES	A-19

LIST OF ILLUSTRATIONS

Figure	Title	Page
A-1	DISTRIBUTION OF ERLANGS BY MAJOR SYSTEM	A-2
A-2	CONUS/CANADA ERLANG FLOWS BY MILEAGE	A-7
A-3	ORIGINATING AUTOVON TRAFFIC BY LOCATION	A-8
A-4	INTER-AREA AUTOVON TRAFFIC FLOWS	A-11
A-5	DISTRIBUTION OF NON-SWITCHED CONUS VOICE CIRCUITS BY MILEAGE	A-16

LIST OF TABLES

Table	Title	Page
A-I	OPERATIONAL NETS WITHIN AUTOVON	A-5
A-II	DIVISION OF EXISTING CONUS AUTOVON TRAFFIC INTO OPERATIONAL AND ADMINISTRATIVE CATEGORIES	A-4
A-III	CONUS AUTOVON AREA-TO-AREA TRAFFIC FLOWS	A-10
A-IV	DISTRIBUTION OF SECURE VOICE TRAFFIC FLOWS	A-12
A-V	NON-AUTOVON SPECIAL PURPOSE OPERATIONAL NETS AND THEIR MONTHLY LEASE COSTS	A-14

I. INTRODUCTION

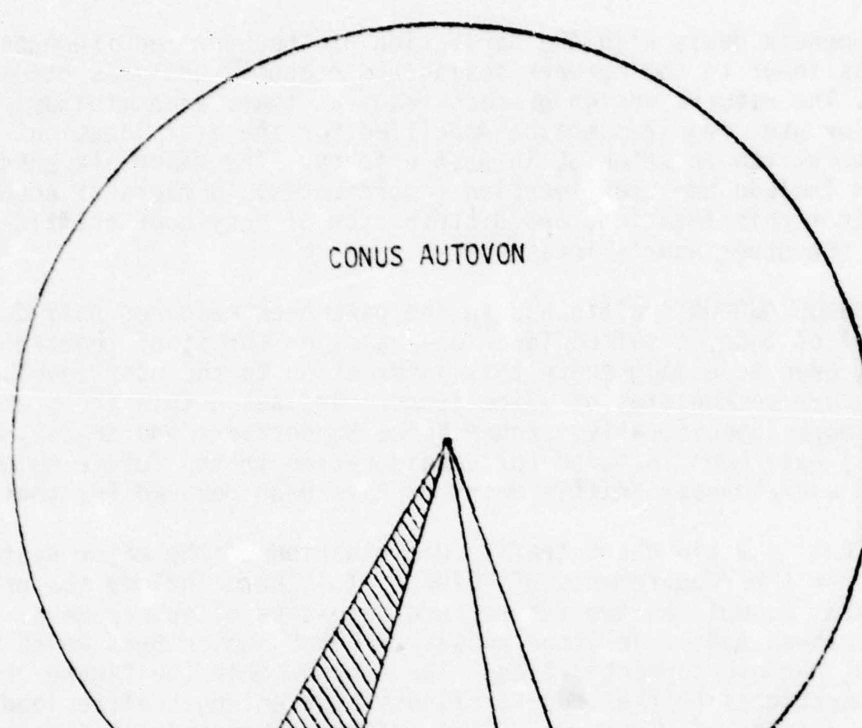
This Appendix deals with the derivation of the user requirements which were used as input to the network design and economic analysis studies for AUTOVON II. The network design process requires that, as a minimum, the level of detail for user requirements be specified for the user location, rather than for the switch location as in past efforts. The major elements of this information include the user location (coordinates), numbers of access lines emanating from this location, and distribution of busy hour traffic loadings to each of the other user's locations.

Since CONUS AUOVON traffic has in the past been measured only down to the level of today's switch locations, a major thrust of requirements efforts has been to disaggregate this information to the user level. In addition, other communities of voice subscribers not within the present AUTOVON network (specifically, Secure Voice Subscribers and Special Purpose subscribers) have been included for consideration in the future AUTOVON II system, and user-to-user traffic matrices have been derived for these communities.

Figure A-1 is a pie chart traffic distribution of the major systems considered for the requirements of AUTOVON II. These include the present CONUS AUTOVON, as well as two future candidate sets of subscribers: Secure Voice Subscribers and a selected subset of CONUS subscribers which today have special purpose connectivities. The areas within the figure are roughly proportional to the amounts of busy-hour erlang traffic loadings for each system considered. As shown, CONUS AUTOVON accounted for the majority of traffic with about 5,000 erlangs of traffic. In addition, a specific set of non-switched voice users (shown as S.P. for special purpose on the figure) were also included for consideration in AUTOVON II requirements. Finally, two traffic components of the proposed secure voice subscriber community were considered; one to represent the intra-Secure Voice traffic and one to represent the AUTOVON to Secure Voice crossover traffic. Also not included were crossover traffic potentials of the special purpose users due to a lack of knowledge of their traffic patterns. Basically, for each major system above, a user-to-user level of traffic matrix was generated for use in sizing the six alternative networks of this effort. Before proceeding into a more detailed summary of these matrices, it is necessary to review the trunking structure of the six alternatives.

Three of the alternatives (Alternatives 1, 2, and 5) represent candidate networks whose backbone trunking is dedicated to the network on a full period basis. The other three, Alternatives 3, 4, and 6, represent approaches where some form of commercially available trunking will be utilized on a shared, nondedicated basis. Certain subscribers of the major systems mentioned above have missions highly related to the needs of national security.

It is felt that these operationally oriented subscribers will place demands for enhanced capability (specifically in the area of precedence and preemption) on the future AUTOVON II which cannot be met within the shared, nondedicated



LEGEND:

SVS-VON = Traffic Between AUTOVON and Secure Voice Subscribers.

SVS = Secure Voice Traffic

S.P. = Special Purpose Traffic

Figure A-1. Distribution of Erlangs by Major System

trunking provided in the latter group of alternatives. Consequently, for the purposes of sizing a network satisfying the requirements of both types of users in Alternatives 3, 4, and 6, two separate network components were considered; one to handle the great bulk of administrative traffic on a shared basis, and the other, a dedicated network, to provide precedence and preemption capability to these operational users. This breakout into components is for sizing purposes only and should not be construed to imply a lack of accessibility of the administrative component by the operational user. Accordingly, it was necessary for network design and economic analysis to partition the traffic matrices mentioned above into the two components, administrative and operational. A brief rationale for doing this, as well as the derivation of each of these matrices, follows.

II. CONUS AUTOVON

The present CONUS AUTOVON (I) is a major requirements input for AUTOVON II. Today, its traffic is measured monthly for the busy hour and accurately reflects traffic flow in the form of a switch-to-switch matrix.

In order to get the needed granularity to expand this switch-to-switch matrix to a geographic location-to-location traffic matrix, the following procedure was developed. A data base of current AUTOVON I access lines homed to one of the present 59 CONUS/Canada switches was created by query from the DCA Circuit Directory (a DCA data base of all DCS circuits worldwide). Each individual cell in the available switch-to-switch matrix was expanded into a submatrix whose rows represent the locations homed to the originating switch, and whose columns represent the locations homed to the destination switch. The DCA circuit Directory provided the numbers and types of access lines homed to each switch. The resulting location-to-location array consisted of a total of approximately 734 locations and 4940 erlangs of traffic (1977 average figures). Based on the results of a DCEC visit to NORAD during May 1978, this array was then adjusted to reflect a planned reduction of the SAGE BUIC AUTOVON configuration. This adjustment resulted in a reduction of the 1977 traffic to 4771 erlangs.

The location-to-location traffic matrix was subdivided into an operational and an administrative component. This was accomplished through use of the purpose-use code indicator associated with each circuit. The codes which identified operational usage are shown in Table A-I. This particular collection of networks was chosen through the process of engineering consensus and was used to estimate the totality of operational traffic within the AUTOVON I switched network requiring precedence and preemption capabilities.

This analysis resulted in two matrices as shown in Table A-II below.

TABLE A-II. DIVISION OF EXISTING CONUS AUTOVON TRAFFIC INTO OPERATIONAL AND ADMINISTRATIVE CATEGORIES

Matrix Component	Erlangs of Traffic
Operational	65
Administrative	4706

TABLE A-I. OPERATIONAL NETS WITHIN AUTOVON

	PURPOSE/ USE CODE	NO. OF AUTOVON CIRCUITS	NAME OF NET
1	CD	1	NATIONAL WARNING SYSTEM
2	DJ	52	NATIONAL MILITARY COMMAND AND CONTROL VOICE NETWORK
3	DW	1	USAFE HQ COMMAND AND CONTROL
4	JA	0	SAC PRIMARY ALERT SYSTEM CONTROL
5	JD	2	SAC COMMAND AND CONTROL NETWORK (465L)
6	JG	0	SAC TELEPHONE NETWORK
7	JL	5	SAC POST ATTACK COMMAND AND CONTROL SYSTEM (GROUND ENVIRONMENT)
8	KK	131	ARMY COMMAND AND CONTROL NETWORK
9	KR	2	ANMCC NETWORK
10	PA	1	AF COMMAND POST VOICE NETWORK
11	PC	0	AF COMMAND NETWORK
12	QM	86	MAC COMMAND CENTRAL VOICE CIRCUITS
13	TB	54	TAC COMMAND AND CONTROL VOICE ALERTING SYSTEM
14	TC	0	TAC OPERATIONS SUPPORT VOICE SYSTEM NETWORK
15	WA	0	ANTISUBMARINE WARFARE NETWORK
16	WC	0	WORLDWIDE COMMAND AND CONTROL SYSTEM
17	YC	5	CINCLANT COMMAND AND CONTROL NETWORK
18	YK	2165	SAGE AUTOVON SWITCHED NETWORK
19	ZA	5	SATELLITE CONTROL/REPORTING COMMUNICATIONS
		2510	

The AUTOVON traffic (both Operational and Administrative) described in this section was used as input to a number of statistical/graphical procedures for examining and understanding the overall nature of this flow of traffic.

First, a histogram was developed which shows the distribution of erlang flows of traffic on a mileage basis for subscribers in CONUS and Canada. This is shown in Figure A-2. The distribution generally follows the form of an exponential distribution with the exception of a noticeable concentration in the 2,200 to 2,600 mile (3,540 to 4,183 km) range. This is probably accounted for by the relatively large numbers of subscribers on the East and West coasts who communicate between one another. This type of histogram is useful in sorting the flows of traffic by distance and gives an indication of the percentage of flow exceeding any given distance. This particular histogram represents traffic between subscribers whose coordinates were available from the Geographic Location File (a DCEC data base consisting of geographic location names and coordinates) and each of whose locations were in the range of 65 to 125 degrees west longitude and 25 to 55 degrees north latitude.

To give some insight into where this traffic originated over the same geographical base, Figure A-3 was produced using the AUTOVON traffic location-to-location file and the plotting capability of the DCEC Hybrid Simulation Facility. The center of the circle represents a subscriber's geographic location and the area of the circle is proportional to the number of erlangs originating from that subscriber location. The location with the largest number of originating erlangs of traffic is the Pentagon, which serves as a reference and is represented by a circle with an arbitrary radius of 50 miles. Intersecting or concentric circles indicate areas of geographically dense subscriber locations. In addition, circles of relatively large geographic areas correspondingly indicate a high density of originating traffic.

As expected, Figure A-3 indicates large masses of traffic density along the eastern, southern, and western coastlines. In addition, the Metropolitan areas of Washington, D.C., San Diego, Los Angeles, Norfolk, Philadelphia, St. Louis, and Boston exhibit relatively dense areas of traffic. Over the entire CONUS, there appears to be a relatively uniform spread of originating traffic in the approximate eastern half of the country and an irregular, much lower concentration in the western half.

In order to indicate where the AUTOVON traffic flowed on a geographical basis, it was first necessary to define specific geographic areas and then aggregate the 734x734 location-to-location traffic matrix over these

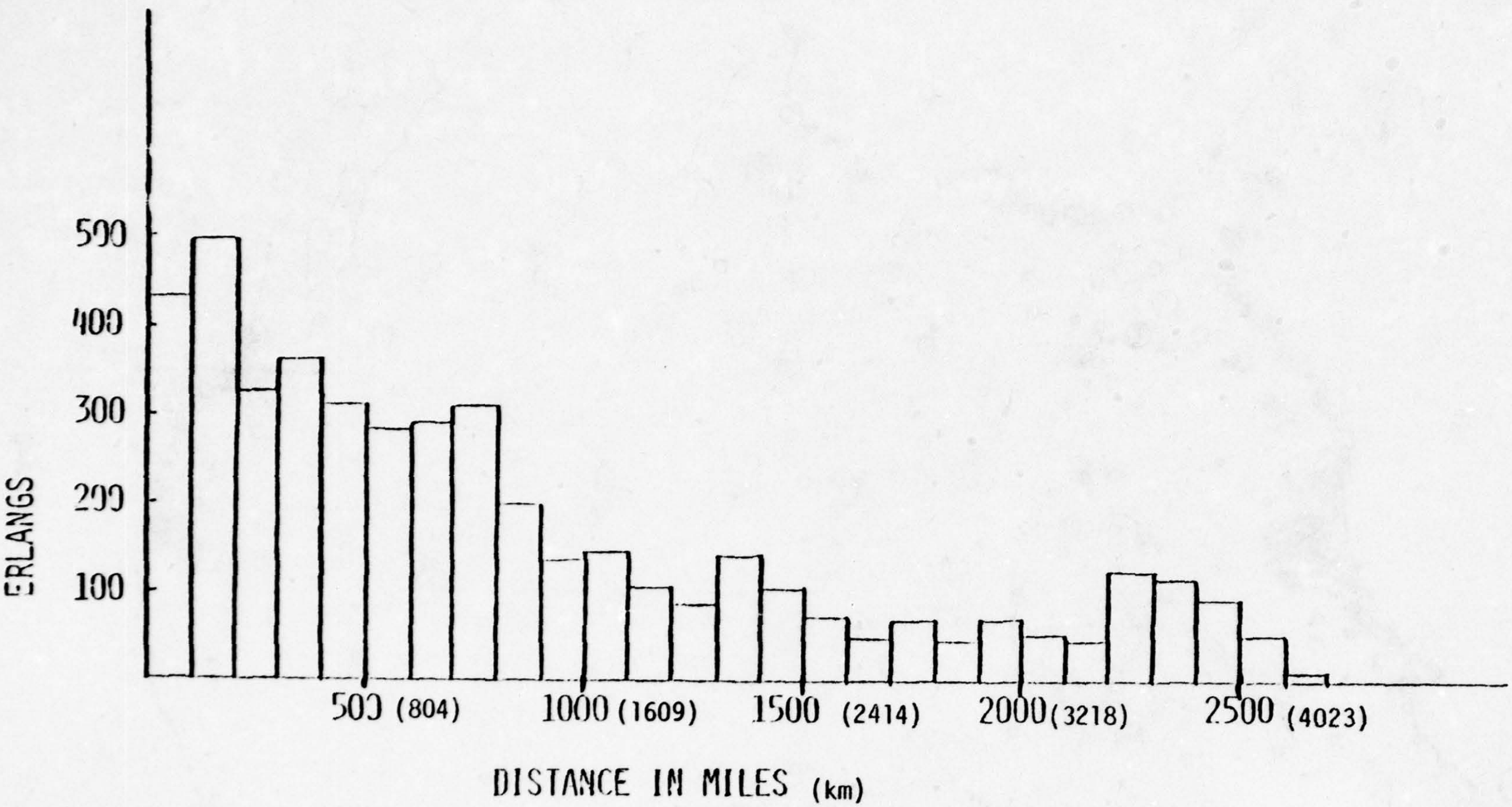


Figure A-2. CONUS/CANADA Erlang Flows by Mileage

Figure A-3. Originating AUTOVON Traffic by Location

areas. The areas chosen for this purpose were the eight (A through H) DCA CONUS areas [1] with Canada added as a ninth. The aggregated traffic matrix is shown in Table A-III. The intra-area flows comprised about 30% of the total, with Area B as shown in Figure A-4 contributing the largest traffic flow. The remaining portions of the matrix, representing inter-area flows, were combined into total traffic flowing between the 36 possible FROM-TO pairs of areas. These 36 flows then were ranked on the basis of a scale of 1 to 10 and portrayed graphically as shown in Figure A-4. The areas are shown with nodes at their approximate centroids and the inter-area flows are indicated by connecting lines whose relative thickness is represented by these rankings. Three observations can be made regarding Figure A-4:

a. Very sparse flows exist between the eight CONUS areas and Canada.

b. The heaviest flows occur between areas B, C, D, and E.

c. Heavy flows are shown between area B and all other areas with the exception of area F.

TABLE A-III. CONUS AUTOVON AREA-TO-AREA TRAFFIC FLOWS

	A	B	C	D	E	F	G	H	CA
A	72	139	39	45	26	5	13	14	2
B	117	546	220	166	188	19	58	93	2
C	37	245	224	84	96	13	26	32	1
D	34	165	71	178	91	17	34	25	4
E	22	145	93	100	164	13	27	34	1
F	3	15	6	10	6	16	8	6	1
G	14	88	30	42	33	16	69	50	1
H	16	131	39	36	39	19	51	69	1
CA	2	1	1	4	0	1	0	0	32

TOTAL	4513
INTRA-AREA	1369
INTER-AREA	3144

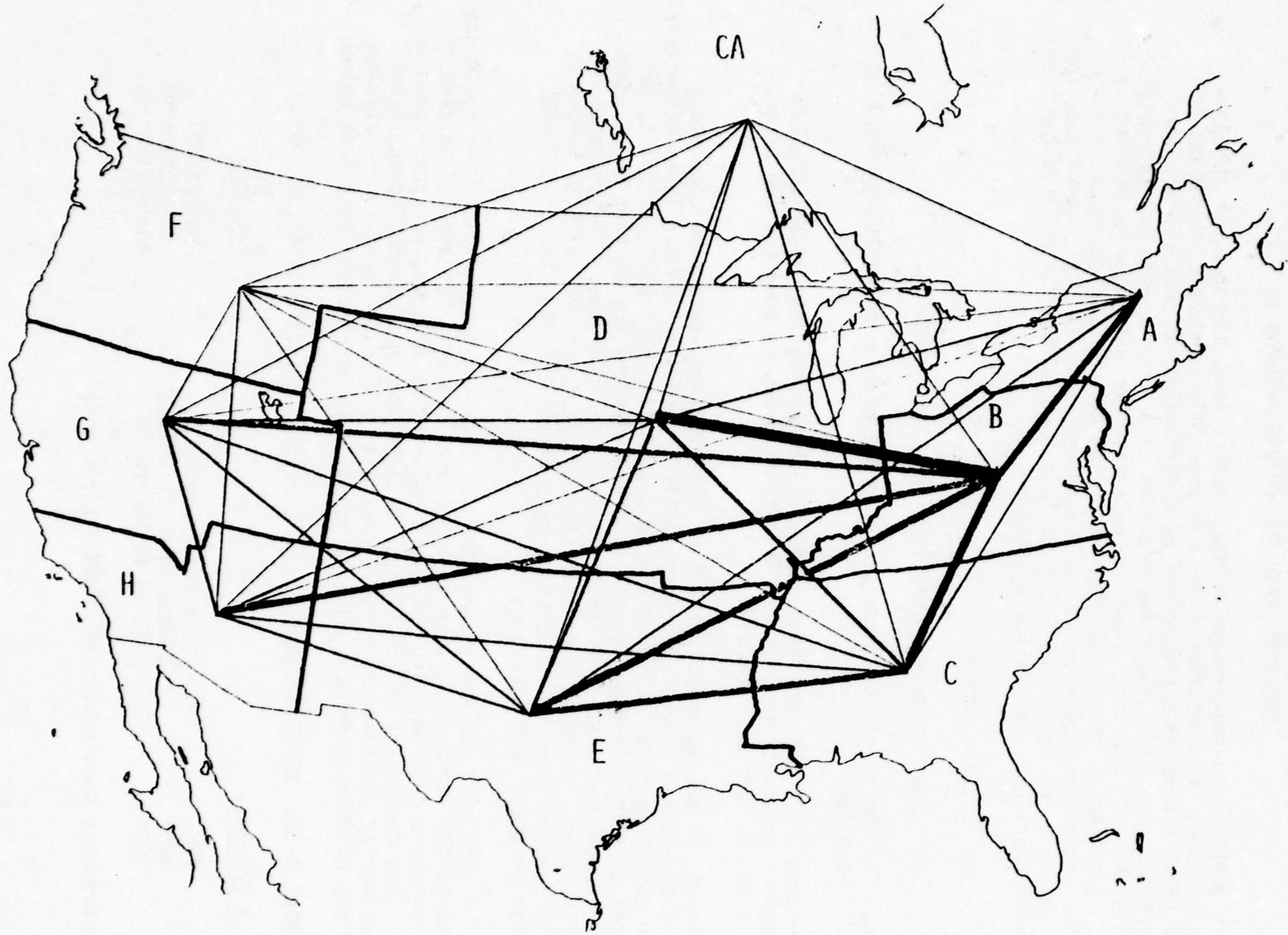


Figure A-4. Inter-Area AUTOVON Traffic Flows

III. SECURE VOICE SUBSCRIBER COMMUNITY AND THEIR INTERFACE WITH THE FUTURE AUTOVON II

In addition to the present AUTOVON subscribers mentioned in the previous section, the subscribers who are presently candidates for secure voice service were also considered as contributors of requirements for AUTOVON II. The basic input for creation of a secure voice traffic matrix began with a JCS approved secure voice subscriber data base maintained by DCEC. A subset of this file, prepared by DCEC, was used as input to a traffic generation procedure to be discussed next. This file provided, for each secure voice subscriber location (a subset of the 734 AUTOVON locations discussed earlier), the following items:

a. The location number.

b. The number of subscriber lines from that location.

c. The number of busy hour secure voice erlangs originating from that location.

There were 261 CONUS locations involved, comprising 1541 lines with 545 erlangs of originating traffic. This traffic was assumed to flow according to the following procedure.

First, it was assumed that 80% of this traffic would flow completely within the secure voice subscriber family of users in CONUS. This intra-secure voice community traffic, for the purposes of Alternatives 3, 4, and 6, was classed as primarily operational in nature, for the reason that these users have a documented justification to talk in a secure mode. For purposes of traffic flows, it was assumed that these 436 erlangs (80% of 545) flowed to the 261 secure voice user locations proportional to the flow of AUTOVON traffic to these same locations.

The remaining 20% was assumed to flow from the secure voice user community to the AUTOVON community, with an additional matching 20% assumed to flow in the reverse direction. Thus, 120% of 545, or 654 erlangs, was considered in all. This double set of 109 (20% of 545) erlangs was assumed to represent the primarily administrative needs of the secure voice users to communicate with the AUTOVON community. This process is summarized in Table A-IV below:

TABLE A-IV. DISTRIBUTION OF SECURE VOICE SUBSCRIBER TRAFFIC FLOWS

# Erlangs	Flow	Category
436	Intra-Secure Voice	Operational
109*	Secure Voice to AUTOVON	Administrative
109*	AUTOVON to Secure Voice	Administrative

(* represents secure voice/AUTOVON interaction)

IV. SPECIAL PURPOSE USERS AS POTENTIAL CANDIDATES FOR AUTOVON II

To account for the likelihood that some of today's voice special purpose (non-switched) networks would opt for service in the common user network of tomorrow's AUTOVON II, an estimated set of traffic arising from these circuits was included in the AUTOVON II requirements. At this time, no detailed judgement can be made as to whether or not such inclusion would be deemed economically feasible. However, for the purposes of completeness it was felt that at least a minimal set of these subscribers should be addressed.

To this end, a query was made of the DCA circuit directory for circuits which met all the following criteria:

a. The circuit was a voice, non-DCS-switched circuit, or alternative voice/record non-DCS-switched circuit (as determined by its Type Service Code, either V or R).

b. The circuit was of an operational nature as determmined by its Purpose-Use Code belonging to the specially defined set of 19 discussed under paragraph 2 of this appendix.

c. Its endpoints lay within the CONUS.

d. Its endpoints determined separate geographic locations (non-zero mileage).

That is, the special purpose CONUS circuits belonging to the same 19 operational networks considered for the switched case earlier were used as candidate operational users. Table A-V shows these nets as well as their present approximate monthly lease costs. These costs totaled approximately $5.1 million per year. The number of circuits was 805.

The actual traffic patterns over these circuits are not presently known. Accordingly, an average figure of one-tenth erlang was assumed to flow over these circuits in each direction. This figure results from an average 5 minute holding time per busy hour call and an average of 1.2 calls per busy hour. A total of 161 erlangs was generated between end points. For purposes of Alternatives 3, 4, and 6, this was assumed to be of a predominantly operational nature. The number of different locations corresponding to the termini of these circuits was 306, of which 201 were coincident with the 734 discussed previously, and the remaining 105 constituted additional CONUS locations. Thus, the inclusion of this particular subset of special purpose non-switched users increased the location base by about 15 percent. The effect of considering these circuits transcends the increase of the overall erlang load. Each new location added requires additional homing which will add to the costs of the access area.

TABLE A-V. NON-AUTOVON SPECIAL PURPOSE OPERATIONAL NETS AND THEIR MONTHLY LEASE COSTS

	PURPOSE/ USE CODE	NAME	MONTHLY LEASE COSTS INTRA-CONUS, DOLLARS
1	CD	NATIONAL WARNING SYSTEM	116,000
2	DJ	NATIONAL MILITARY COMMAND AND CONTROL VOICE NETWORK	82,600
3	DW	USAFE HQ COMMAND AND CONTROL	---
4	JA	SAC PRIMARY ALERT SYSTEM CONTROL	83,700
5	JD	SAC COMMAND AND CONTROL NETWORK (465L)	15,300
6	JG	SAC TELEPHONE NETWORK	24,700
7	JL	SAC POST ATTACK COMMAND AND CONTROL SYSTEM (GROUND ENVIRONMENT)	5,400
8	KK	ARMY COMMAND AND CONTROL NETWORK	3,000
9	KR	ANMCC NETWORK	380
10	PA	AF COMMAND POST VOICE NETWORK	40,000
11	PC	AF COMMAND NETWORK	748
12	QM	MAC COMMAND CENTRAL VOICE CIRCUITS	5,000
13	TB	TAC COMMAND AND CONTROL VOICE ALERTING SYSTEM	26,400
14	TC	TAC OPERATIONS SUPPORT VOICE SYSTEM NETWORK	12,100
15	WA	ANTISUBMARINE WARFARE NETWORK	7,500
16	WC	WORLDWIDE COMMAND AND CONTROL SYSTEM	---
17	YC	CINCLANT COMMAND AND CONTROL NETWORK	3,000
18	YK	SAGE AUTOVON SWITCHED NETWORK	---
19	ZA	SATELLITE CONTROL/REPORTING COMMUNICATIONS	768

In order to gain a better insight into the nature of these special purpose voice circuits in the CONUS, Figure A-5 shows the mileage distribution of the total (10,644) circuits (not just those from the 19 operational nets above). A significant feature is their relatively short mileages. Over 92 percent of these are within 500 miles (805 km) and 76 percent within 200 miles (322 km). This fact will surely tend to inhibit the conversion of these users into a common user voice network, from a purely economic point of view.

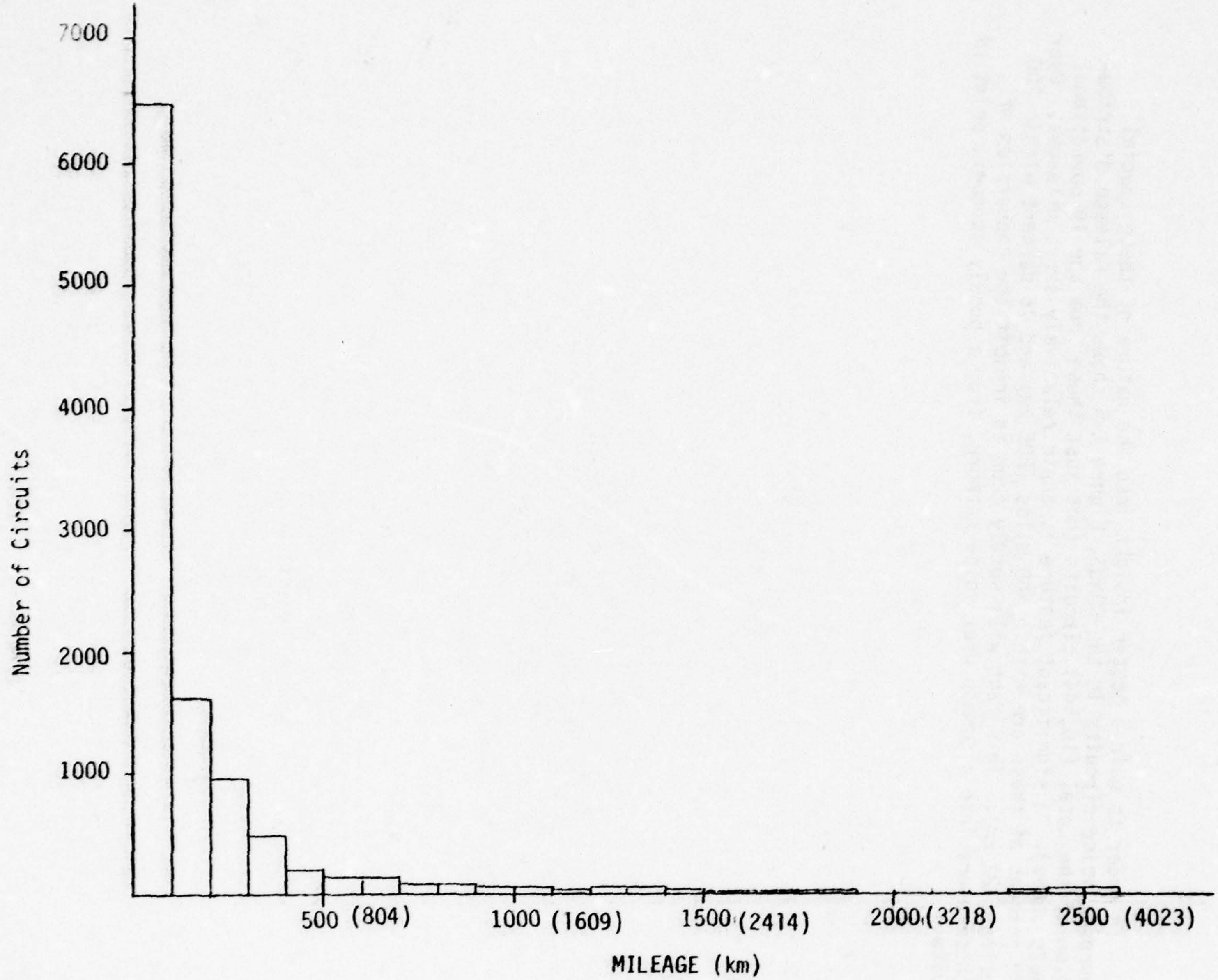


Figure A-5. Distribution of Non-Switched CONUS Voice Circuits by Mileage

V. VOICE USER CAPABILITY OBJECTIVES

The requirements described in this appendix are concerned with the derivation of traffic matrices at the level of the subscriber and his location. In addition to responding to these traffic levels, the network must also respond to the user's demand for special services and capabilities that are required for his specific mission. These are collectively referred to as voice user capabilities objectives and are fully discussed in [2].

VI. SUMMARY

This appendix discusses the manner in which traffic flow matrices, at the user location geographic level, have been derived for three principal CONUS subscriber communities: AUTOVON, Secure Voice users, and Special Purpose users. The need to categorize this traffic into administrative and operational components is discussed. Some insight into the nature of the geographical flow of this traffic was developed. For AUTOVON, a major assumption in going from the switch-to-switch level to the location-to-location level is the assignment of weights to a known distribution of access lines. For the secure voice users, a major assumption was that its flow would be approximated by that within AUTOVON. For the Special Purpose users, traffic flow was solely determined by the termini of the locations.

The traffic flow matrices represent the best available estimate of unmeasured quantities using rational assumptions. The inference should not be made that they represent measured traffic flows between users, because these are presently unavailable at the user location level. Indeed, one vital capability of the future CONUS AUTOVON II should be the ability to collect and record detailed statistical summaries of the user's utilization of all the network's resources with indications of hourly, monthly, and seasonal variations. A thorough understanding of these kinds of statistics is a vital ingredient to the design and management of any voice network.

REFERENCES

[1] DCA Circular 310-65-1, "Circuit and Trunk File Data Elements and Codes Manual of the Defense Communications System (DCS)," June 1969.

[2] DCEC Technical Report, TR 20-78, "The Defense Communications System (DCS) FY 82 and Beyond (U)," December 1978, Chapter III (Secret).

APPENDIX B

COMMON CHANNEL SIGNALING AND AUTOVON ROUTING PHILOSOPHY

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	B-1
II.	CCS SERVICE FEATURES	B-3
	1. Signaling Speed	B-3
	2. Information Capacity	B-3
	3. Two-Way Signaling	B-3
	4. Separate Signaling Channel	B-4
	5. Compatibility with International Signaling	B-4
	6. Reliability	B-4
	7. Flexibility	B-4
	8. Transmission Quality Improvement	B-4
III.	AUTOVON I	B-5
IV.	AUTOVON II	B-9
V.	ASSOCIATED VS NON-ASSOCIATED SIGNALING	B-12
VI.	INTERSWITCH SIGNALING SCHEMES	B-17
VII.	AUTOVON ROUTING	B-20
	REFERENCES	B-23

LIST OF ILLUSTRATIONS

Figure	Title	Page
B-1	SF/MF VS CCS	B-2
B-2	HARDWARE MODIFICATION OF AECo/AT&T NO. 5 CROSS-BAR	B-10
B-3	BELL SYSTEM'S INTERTOLL CCIS NETWORK STRUCTURE	B-13
B-4	CCS NETWORK CONNECTIVITY	B-14
B-5	INDEX OF SURVIVABILITY	B-16
B-6	CALL SETUP TIME VS BIT ERROR RATE	B-18
B-7	SURVIVABILITY COMPARISON	B-22

LIST OF TABLES

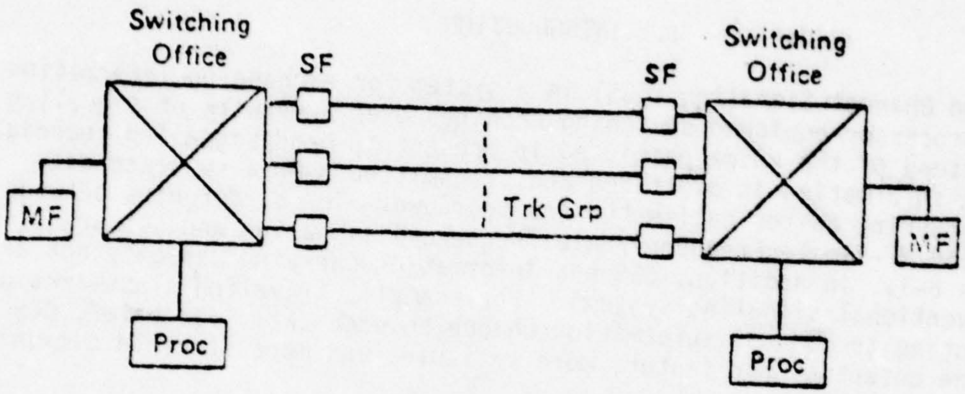
Table	Title	Page
B-I	SURVIVABILITY ENHANCEMENT	B-6
B-II	CCS COSTS FOR CONUS/CSN AUTOVON	B-7
B-III	ALTERNATIVE 1 HARDWARE COSTS (1976) FOR CCS	B-11
B-IV	CCS TRANSMISSION COSTS	B-9
B-V	ALTERNATIVES 3 AND 4	B-9

I. INTRODUCTION

Common Channel Signaling (CCS) is a system for exchanging information between processor-equipped switching machines over a network of signaling links instead of the voice path used in present in-band signaling techniques. Signaling information is digitized and transmitted over a separate data channel insuring faster call setup and teardown. The differences between in-band (SF/MF-Single Frequency/Multifrequency) signaling and CCS are illustrated in Figure B-1. In addition, CCS has information-carrying capacity not available with conventional signaling systems. For example, traveling classmarks can carry routing or control information unique to each call. In brief, CCS offers the potential for faster, more reliable, and more flexible communications services.

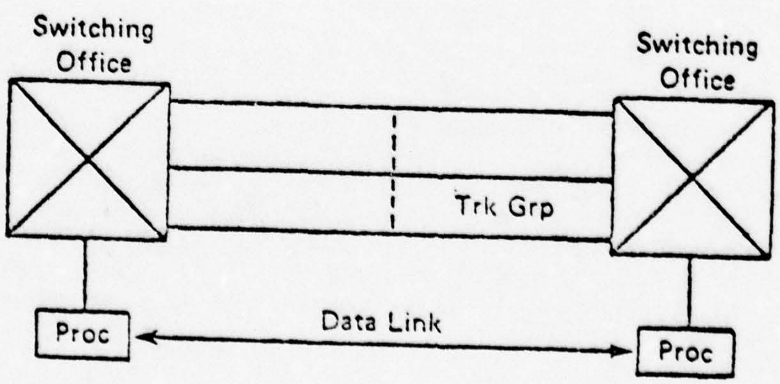
This appendix addresses the introduction of CCS into the present day AUTOVON from an economic and survivability enhancement viewpoint. For AUTOVON II, the associated transmission costs for the CCS network are presented for Alternatives 1 through 6, and certain key technical issues of CCS implementation are pointed out for future analysis. Finally, the implications of CCS to AUTOVON routing are discussed.

SF/MF Signaling



- Slow
- In-Band
- Low Capacity
- Inflexible

CCS



- Fast
- Separate Channel
- High Capacity
- Flexible

Figure B-1. SF/MF vs CCS

II. CCS SERVICE FEATURES

CCS offers a number of important advantages over present in-band signaling techniques. The major advantages are briefly described in the following paragraphs.

1. SIGNALING SPEED

Because CCS passes signals at higher speeds than conventional signaling systems, calls can be set up and taken down faster. This benefits the calling customer in reduced post-dialing delay. In addition, the holding time of trunks and switching equipment is reduced, permitting more efficient use of these facilities. At present, call setup times vary with the number of links in the connection. This variation will decrease as the CCS network grows. As a result, the customer will experience a more uniform call setup time, regardless of the number of links involved. The significance of more rapid call setup time can be illustrated by comparing the time to set up a connection between two end offices over two toll connecting trunks and over one intertoll trunk. Such a connection represents about 85 percent of the toll call traffic. Assuming present-day electromechanical switching offices and in-band single-frequency supervisory signaling together with multifrequency inter-register signaling, a connection can be set up in about 10 seconds. With CCS providing the signaling function and with electronic switching offices, the call setup time will be on the order of 1-2 seconds. The most significant portion of this improvement is due to the use of CCS in place of present-day conventional signaling methods. This time may be still further improved by increasing the speed of the signaling links even more, although switching office handling time rapidly becomes a limiting factor.

2. INFORMATION CAPACITY

CCS inherently has information-carrying capacity not available with conventional signaling systems. Per-call information (traveling classmarks) can carry routing or control information unique to each individual message. Thus, new and improved customer services are made possible by CCS. In addition, more efficient operation of the telephone network can be achieved by using CCS links to transfer network management information.

3. TWO-WAY SIGNALING

CCS uses a separate two-way data link; signals can be sent in both directions of transmission simultaneously. In addition, signaling can take place simultaneously with conversations on the trunk. This makes it possible, for example, to process a request in the backward direction for the telephone number of the calling line (calling line identification), providing the switching machines are properly programmed.

4. SEPARATE SIGNALING CHANNEL

Because CCS utilizes a path which is independent of the trunk voice path, other advantages are realized. Interactions between voice and supervisory signals, such as "talk off" (disconnect of the talking path by voice signals), are eliminated. Also eliminated are present bandwidth restrictions on the use of the voice band, thereby insuring compatibility of data operations and signaling. Thus, in an all-CCS connection, the network will be more transparent to the customer. In addition, the possibility of fraud by simulation of conventional in-band tone signals is reduced and would, in an all-CCS network, be eliminated. Another disadvantage of in-band signaling is also eliminated by CCS; this is the occurrence of mass seizures which result from the loss of in-band tones on idle trunks (due to carrier failure).

5. COMPATIBILITY WITH INTERNATIONAL SIGNALING

It is expected that international telephone traffic will make use of CCITT Signaling System No. 6, the most recent of the standard international systems. By providing translation equipment at international switching offices, it will be possible to integrate international and domestic traffic more efficiently than presently possible (perhaps in common trunk groups).

6. RELIABILITY

CCS offers the potential of more reliable transfer of address information than present conventional methods.

7. FLEXIBILITY

One of the outstanding characteristics of CCS, relating to network operation and customer service, is that the CCS message format allows considerable latitude and flexibility in transmitting all types of signaling information. This includes signals that might be used for future services not presently defined.

8. TRANSMISSION QUALITY IMPROVEMENT

The implementation of CCS will see positive improvements in transmission quality. Major improvement will be noted in trunks with several links in tandem. In present D3 systems, encoding is performed with only 7-5/6 bits, rather than 8. This occurs because the 8th bit in every 6th and 12th frame is allocated to the transmission of signaling information within the system bit stream. The result of this "bit robbing" is increased distortion. CCS will permit the use of full 8-bit encoding, and thus eliminate this form of degradation.

III. AUTOVON I

There are substantial costs involved in modifying the present AUTOVON switches for CCS. Other than the service features mentioned in the previous section, the main benefits to be derived from CCS are survivability enhancement due to more flexible routing control, and a reduction in the erlang load due to reduced call setup and teardown times. The latter would produce a true cost benefit in that transmission costs vary almost linearly, under present tariffs, with the erlang load. A simple calculation can demonstrate this savings. Assume the following:

- Use the statistics presented in paragraph 2,a on call setup time for a connection between two end offices over two toll connecting trunks and over one intertoll trunk, i.e., 10 seconds for in-band signaling, and assume 1 second for CCS.
- Assume an average call holding time of 180 seconds for AUTOVON, including call setup.
- Let λ be the average call arrival rate (calls per second) for AUTOVON.

The erlang load is then 180λ for inband signaling and 171λ for CCS, which is a 5% reduction; however, note that the average path length is about 1.5 links in the present AUTOVON so that any appreciable load reduction is unlikely.

In order to quantify the impact of CCS on survivability we shall assume ideal routing with CCS; i.e., if a path exists, CCS will find it. Using damage scenarios developed for CONUS AUTOVON in support of a MEECN survivability analysis, current polygrid routing was compared with ideal routing. This comparison is depicted in Table B-I for three levels of damage (number of switches destroyed) where the number of node pairs unable to commmunicate was measured for both polygrid and ideal routing. The results suggest that there is little to be gained over polygrid routing.

Finally, the cost of adding CCS to the present AUTOVON is shown in Table B-II. The costs are presented so as to reflect the increased SCAN charges as well as the cost of CCS. The dominant part of the latter is, of course, hardware related. The costs were developed from an AT&T study [1] of AUTOSEVOCOM and are fully documented in [2]. The transmission

TABLE B-I. SURVIVABILITY ENHANCEMENT

(UPPER BOUND TO SURVIVABILITY ENHANCEMENT WITH CCS)

NO. OF SWITCHES DESTROYED*	NO. OF OCCURRENCES*	AVG. I_S (%)	MAX. I_S (%)	NO. OF NODE PAIRS "N" UNABLE TO COMMUNICATE (MAX. CASE)	
				POLYGRID	IDEAL
15	19	0.0	0.0	1,648	1,648
24	30	1.35	5.28	2,407	2,280
31	3	0.74	0.84	2,751	2,728

$$I_S = \frac{N_{poly} - N_{ideal}}{N_{poly}}$$

*MEECN Survivability Study

TABLE B-II. CCS COSTS FOR CONUS/CSN AUTOVON

	ACCESS AREA ($K/MO.)	BACKBONE ($K/MO.)	TOTAL COST ($K/MO.)	TOTAL ANNUAL COST ($K)
PRE OCT '77	3,500	5,166	8,666	103,900
'80 "DO NOTHING"	4,010	5,280	9,290	111,000
'80 ADD CCS	4,010	7,045	11,055	132,663

- CCS WITH FULL ASSOCIATED SIGNALING

  HARDWARE MOD. = $1,740

  4.8 kb/s CCS XMSN* = $ 25

  Δ$ = 7,045-5,280 = $1,765/MO.

*@ .62¢/mi./mo. + $171 per termination.

cost for CCS reflects full associated signaling using a 4.8 kb/s data channel tariffed at 62 cents/mi./mo. plus a termination charge of $171 per month for each signaling link. (This charge was quoted in the AT&T study referenced above.) The VF circuits were costed using the TELPAK tariff of 56.8 cents/mi./mo. and a per-end termination charge of $43.10 per month.

The increased cost of over $20 million a year does not appear to be warranted, at least for the benefits mentioned above. The cost of adding CCS to the present AUTOVON would have to be justified on some other basis. In addition, it would represent a sizable commitment to existing analog switching just when the period of basic termination liability of the present equipment is almost over.

IV. AUTOVON II

Alternatives 1 through 6 are defined in detail in section IV; however, there is a basic distinction to be made between alternative 1 and the others. In Alternative 1, we have selected a subset of the present AUTOVON switches; thus, there is a substantial cost penalty involved in modifying the analog switches for CCS. The majority of switches selected were ESS No. 1's, but for purposes of this analysis there was no restriction to only ESS No. 1's; however, it is possible that modification costs for the AECo and AT&T No. 5 Crossbar could be prohibitively high. The required modifications are depicted in Figure B-2; the costs are presented in Table B-III. The same basic cost parameters discussed in the previous section were used, but the total is multiplied by an inflation factor of 1.55 (from 1976 costs) to reflect 1985 costs. The one-time installation charge and the basic termination liability for the hardware modifications are also shown.

For Alternatives 2 through 6, the associated software and hardware costs for CCS are discussed in Appendix C. It must be emphasized that if other than the standard CCS (e.g., CCITT No. 6 or the Bell Standard CCIS) were implemented there could be substantial software development costs.

The transmission costs for the associated CCS links are given in Table B-IV. These results can be misleading unless the alternatives are fully understood, especially Alternatives 3 and 4. These costs are broken out in more detail below in Table B-V. The costs for the administrative traffic in Alternative 3 reflect just the signaling links paralleling the trunks connecting the digital switches into the ESS No. 4 network. Furthermore, the critical users were only served by 10 switches.

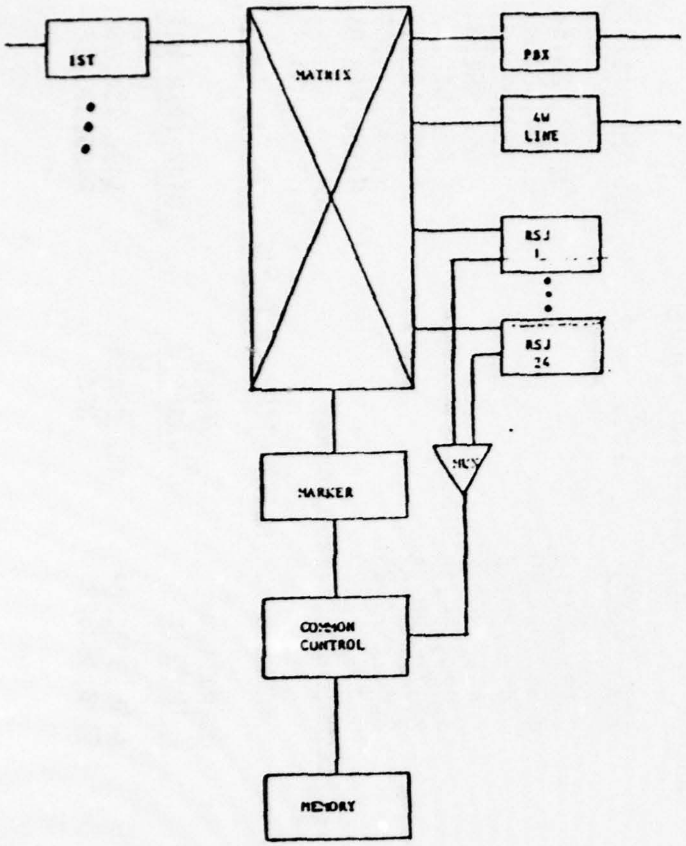
TABLE B-IV. CCS TRANSMISSION COSTS

ALTERNATIVE	XMSN ($/YR)	x1.55 =	1985 XMSN ($/YR)
1	6,104,857.15		9,462,528.58
2	4,351,023.90		6,744,087.05
3	498.734.86		733,039.03
4	435,390.22		674,854.84
5	13,824,866.30		21,428,542.77
6a	2,578,780.35		3,997,109.54
6b	2,858,274.25		4,430,325.09
6c	5,358,612.20		8,305,848.91

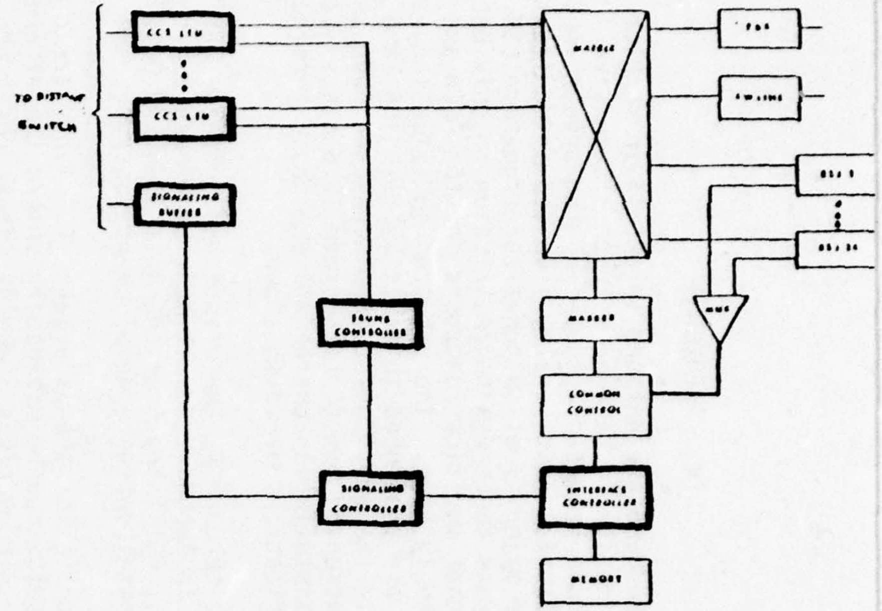
(a=300,b=600,c=1200 miles)

TABLE B-V. ALTERNATIVES 3 AND 4

ALTERNATIVE	OPERATIONAL TRAFFIC	ADMIN TRAFFIC	TOTAL (PER YR)
3	$435,390.22	$63,344.64	$498,734.86
4	$435,390.22	N/A	$435,390.22



EXISTING AECo/AT&T NO. 5X-BAR



CCS MODIFICATION

Figure B-2. Hardware Modification of AECo/AT&T No. 5 Cross-bar

TABLE B-III. ALTERNATIVE 1 HARDWARE COSTS (1976) FOR CCS

			Install./ Term. Liab. ($K)	Annual Recurring Cost ($K)
1	JUL	ESS#1	372	302.4
2	ARL	5 X-BAR	1644.5	1358.3
3	BRE	ESS#1	372	302.4
4	CHA	ESS#1	317	255.2
5	WHN	AECo	349.3	271.04
6	HIL	5 X-BAR	869	692.1
7	JAS	ESS#1	372	302.4
8	LAM	ESS#1	317	255.2
9	LEE	ESS#1	328	264.6
10	LIT	ESS#1	328	264.6
11	MOJ	ESS#1	328	264.6
12	MON	5 X-BAR	953.7	764.9
13	MOU	ESS#1	372	302.4
14	AOA	ESS#1	328	264.6
15	ROC	5 X-BAR	955.9	766.8
16	RSC	AECo	362.5	282.38
17	SOC	ESS#1	372	302.4
18	SWE	ESS#1	328	264.6
19	TLY	ESS#1	372	302.4
20	CED	ESS#1	383	311.9
21	TOL	AECo	634.2	515.79
22	DEL	AECo	397.7	312.62
23	DRA	ESS#1	438	359.1
24	ELL	ESS#1	328	264.6
25	FVW	AECo	693.6	566.82
26	LOD	ESS#1	328	264.6
27	MOS	ESS#1	394	321.3
28	NTG	ESS#1	328	264.6
29	NBW	AECo	481.3	384.44
30	POL	AECo	447.2	355.14
31	SLO	ESS#1	328	264.6
32	SEG	ESS#1	394	321.3
33	STN	ESS#1	372	302.4
34	TOP	AECo	481.3	384.44
35	WIL	ESS#1	372	302.4

INSTALL. $	TERM. LIABILITY		
$3,847,100	$12,594,100	HARDWARE	$13,279,370/yr.
		XMSN	6,104,857.15/yr.
		TOTAL	$19,384,227/yr.

X1.55 (1985)

= $30,133,265/yr.(TOTAL)

V. ASSOCIATED VS NON-ASSOCIATED SIGNALING

In the associated mode of operation, the signals are transferred between two CCS offices over a common signaling link which terminates at the same offices as the group of trunks to which the signaling link has been assigned.

In the non-associated mode of operation, the signals are transferred between two CCS offices over two or more common signaling links in tandem and are processed and forwarded through one or more intermediate signal transfer points (STP). The number of STP's in the signaling path between two CCS offices serving a group of trunks should be kept as low as practicable because an appreciable amount of time may be required to process signals through each STP, thus negating the advantages of the high signaling speed of CCS. When the number of switches is large, there is a significant savings in the installed cost of the non-associated CCS because fewer signaling links are required to attain the same level of continuity of service.

The Bell System implementation of CCIS in their ESS No. 4 network will be as shown in Figure B-3. They currently plan on having 20 STP's in the CONUS toll hierarchy. It should be noted that this has a direct bearing on survivability in that only 20 sites need be targeted to disrupt the operation of this network. The survivability aspects of nonassociated CCS are briefly addressed in the following paragraphs.

Consider the two modes of operation shown in Figure B-4. Define an index of survivability by the following equation:

$$I_s = -\frac{1}{T} \sum_{i,j}^{N} t_{ij},$$

where

T = total busy hour traffic offered to the network.

t_{ij} = the amount of traffic originating at node i destined for node j.

N = the summation evaluated over all node pairs between which there does not exist a signaling path.

The summation gives the total amount of traffic blocked due to the absence of a signaling path between pairs of nodes. This index is a close approximation to the index defined in terms of the overall network blocking probability.

In a prior study [3] for a given circuit-switched network (1973 CONUS AUTOVON with 70 switches and projected 1986 traffic requirements), a signaling channel initially paralleled each link in the network. The signaling channels were then removed whenever the trunk size of the corresponding circuit

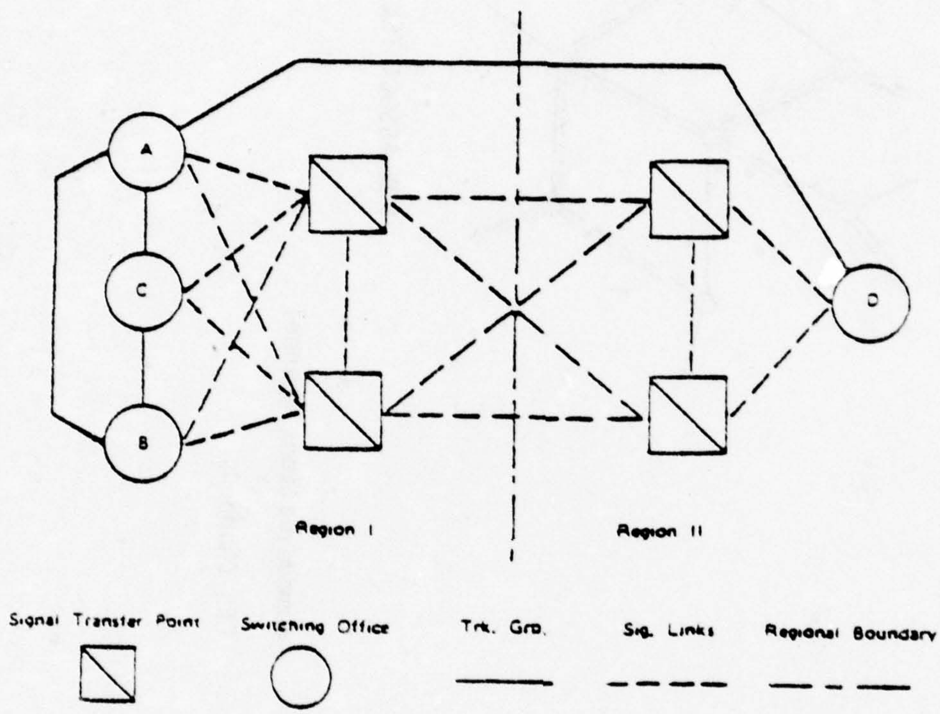


Figure B-3. Bell System's Intertoll CCIS Network Structure

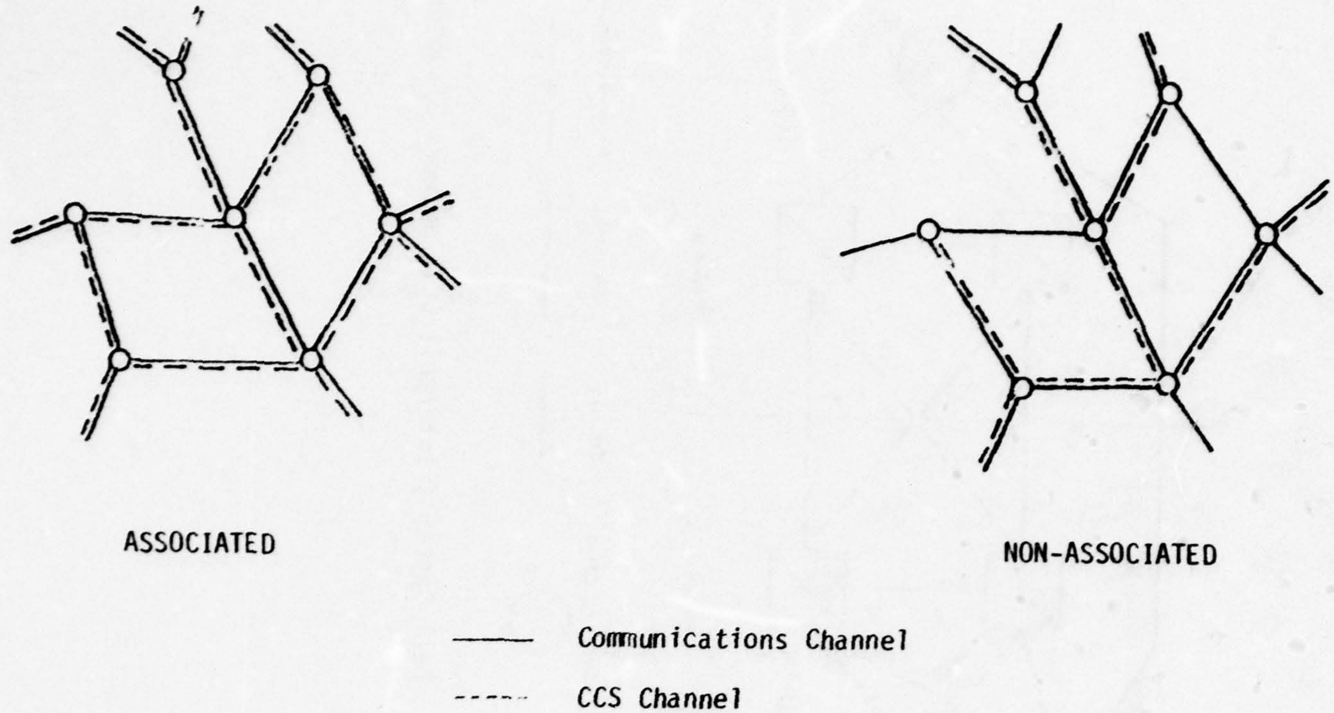


Figure B-4. CCS Network Connectivity

switched link was less than a specified number (from 0 to 20) and network connectivity was not destroyed. A damage scenario was applied to the resulting network and the index of survivability computed. The damage scenario consisted of deleting 14 selected nodes from the network. The results are plotted in Figure B-5 and indicate that at least for this particular damage scenario, it is possible to utilize a sparsely connected signaling and supervision network without serious degradation in performance. Note, however, that in this case every switch is a signal transfer point.

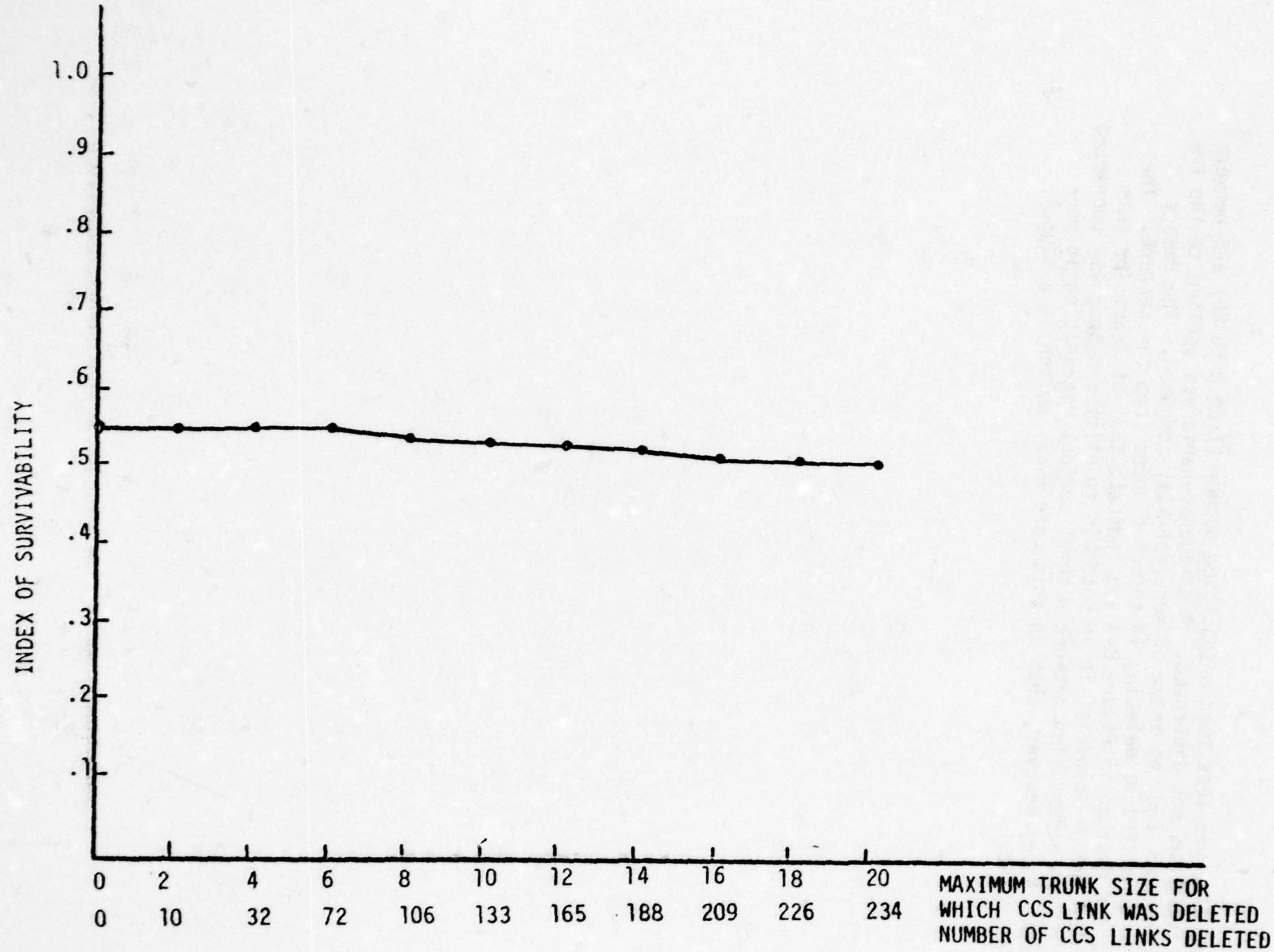


Figure B-5. Index of Survivability

VI. INTERSWITCH SIGNALING SCHEMES

It is beyond the scope of the present study to recommend a specific interswitch signaling system; however, certain observations can be made. It has already been pointed out that substantial software development costs may be incurred in any "off-the-shelf" purchase of digital switching equipment when other than standard CCS is required. By standard, the Bell System Common Channel Interoffice Signaling (CCIS) or CCITT No. 6 CCS is probably implied. CCIS and CCITT No. 6 are very similar except for message format variations. This minor difference can be resolved by translation at internetwork gateways. The use of CCIS wopuld simplify internetwork operation between CONUS AUTOVON and the U.S. domestic telephone network, and CCITT No. 6 would simplify connections between AUTOVON and overseas commercial networks; however, significant technical issues arise if electrical encryption key distribution is required (see [1]).

At the Sixth Plenary Assembly of the CCITT, it was noted that additional improvements could be made in interoffice signaling systems and to optimize the signaling for integrated (voice and data) and digital networks. The participants further recognized that the signaling system should functionally separate the message transfer part, common to all services and applications, from the user parts, specific to each service or application. The CCITT is thus currently developing a new digital common channel signaling system, called CCITT No. 7, which is modeled after CCITT No. 6 and is intended for use in integrated digital networks using stored program control.

In all likelihood AUTOVON II will be a leased service with at least some portion furnished by AT&T. Since AT&T has by far the most extensive transmission plant in this country, the standards, whether for PCM digital hierarchy or common channel signaling, will most certainly be set for the rest of the industry by their lead. Hence, CCIS will certainly be the standard for CONUS. However, Bell Canada has stated it "will not follow the U.S. in using CCIS because Canada is ahead of the U.S. in implementing the integrated digital network". As their digital network evolves, they intend to implement CCITT No. 7 or some similar standard.

Two other likely candidate signaling systems are the TRI-TAC Common Channel Signaling and Federal 6 CCS. The former is being developed by GTE-Sylvania for use between TRI-TAC AN/TTC-39 switches, and the latter, which is a version of CCITT No. 6, was proposed by DCA and the NCS Standards Group for use in all government digital networks. A recent study [4] compared the relative performance of these two schemes over a range of error environments and traffic loading conditions with congestion and queueing effects considered. Typical results are shown in Figure B-6, where call setup time is defined as the time to complete successfully the sequence of messages: CALL INITIATE CALL COMPLETE, and CALL ANSWER. A nominal calling rate of 0.1 per second was used and the bit error rate (BER) was varied from 10^{-6} to 10^{-1} over a line

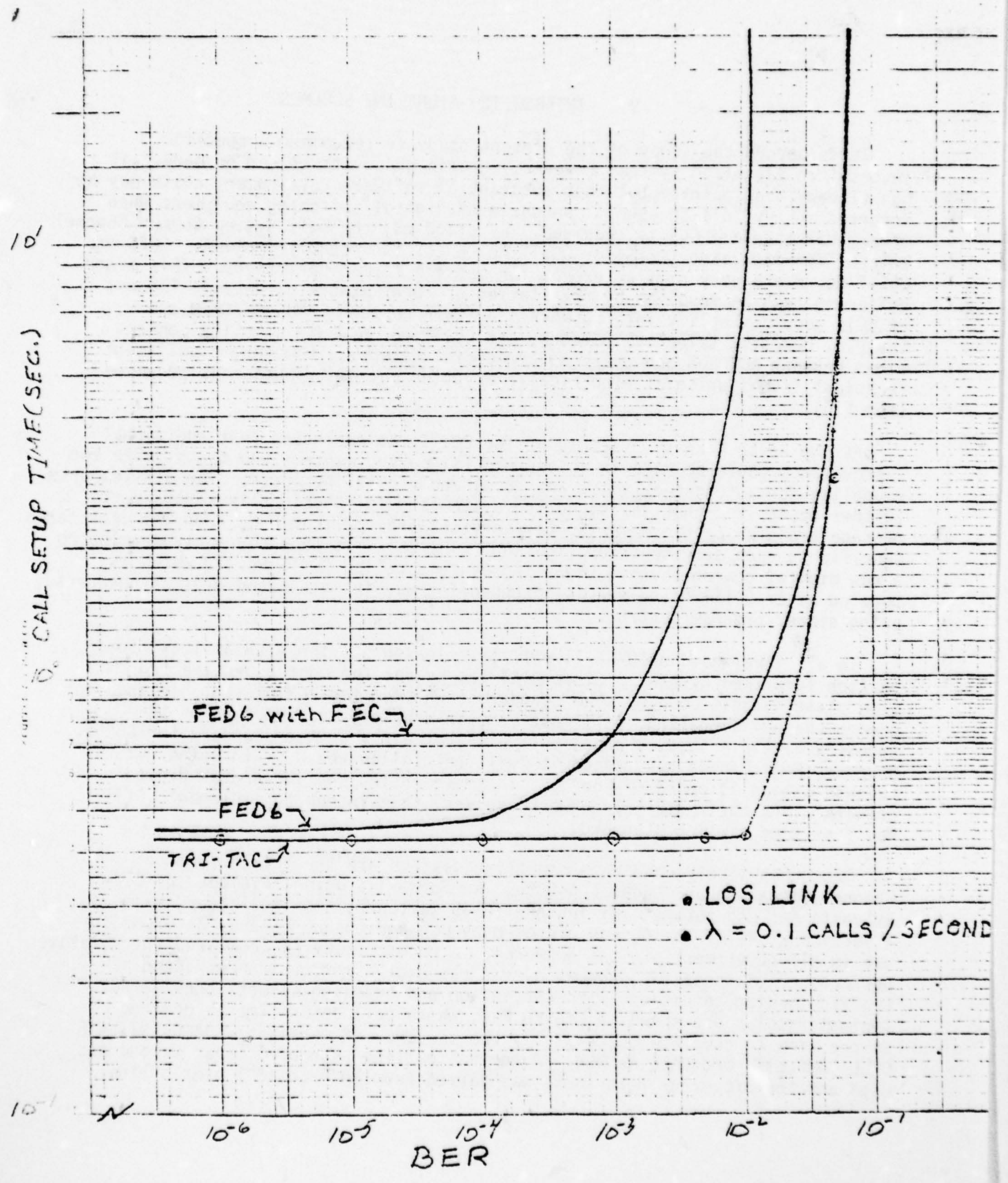


Figure B-6. Call Setup Time vs Bit Error Rate

of site (LOS) link. For the Federal 6 scheme, the analysis was conducted with and without the application of a forward error correction (FEC) technique, which would certainly be desirable over satellite hops. The results generally suggest the following:

- FEC is essential for error rates worse that $5x10^{-3}$.
- FEC schemes suffer no significant performance degradation until error rates become worse than 10^{-2}.
- No significant difference in performance exists between the two FEC schemes (TRI-TAC and FED 6 with FEC).

The TRI-TAC scheme would guarantee compatibility with the tactical world but would have to be modified to allow non-associated operation; however, the TRI-TAC signaling system is the only one discussed which has FEC. Since Federal 6 CCS is based on CCITT No. 6, network interoperation could be a strong argument in its favor. In addition, FED 6 has precedence and preemption features built into the formats.

Federal 6 has two principal modes of operation. One is in strict compliance with CCITT No. 6. This will be used by Federal gateway exchanges when interoperating with non-Federal networks employing CCITT No. 6. An initial address message (IAM), which is sent as the first message of a call setup, usually includes all of the information required by the next exchange to route the call. For Federal interoperation the IAM will contain at least the following signaling information:

- Precedence
- Traffic type indicator
- Controlled access indicator
- Call setup mode indicator
- Satellite delay indicator
- Route control indicator
- Address information.

VII. AUTOVON ROUTING

The routing philosophy in current use within CONUS/ CSN AUTOVON is known as polygrid routing. This term refers also to the network, which was designed by AT&T, in which each switch has a home grid of switches which are directly connected to it. Each switch in the home grid must be connected to the destination switch and at least three other switches in the home grid. All other switches are in the external grid. The routing tables allow considerable flexibility in routing calls to a home grid but constrain the routing within the home grid to a fixed pattern. Polygrid routing tables provide each switch with a maximum of ten alternative switches as the next destination for any call. Route control digits are included in the interswitch signaling sequence. These serve to prevent looping or shuttling of calls. Each switch possesses the requisite logic capability to derive the appropriate route control digit from the received route control digit, information in the routing table, the destination switch selected, and whether or not the current switch is in the home grid of the destination switch.

Polygrid routing allows precedence calls to be routed away from the final destination. These lateral and backward routes enable precedence calls to be routed around damaged areas. Unfortunately, the current procedure for developing routing tables which allow lateral or backward routes is time consuming and unsuited for iterative design algorithms, or for possible use in near-real-time routing table updates. Currrent polygrid routers require at least an hour of central processor time. Additionally, the current polygrid routing tables distribute traffic in a manner that requires excessively expensive trunking.

A proposed routing philosophy, called modified forward routing, leads to algorithms that can generate new routing tables for all CONUS/CSN AUTOVON switches in less than 1 minute. These new algorithms may be used in one of two ways. First, network design programs may use the algorithm in an iterative process for speedy creation of near-minimum-cost networks. Without the use of fast-running routing algorithms, the computer time required for these iterative design algorithms would be prohibitive. Second, the routing tables may be modified in near-real-time in an operational network as connectivity changes occur. This may result either from damage in a crisis situation or hardware failures during normal operations. This adaptive update of fixed routing tables allows the most reliable and flexible use of

the existing communications resources and becomes particularly attractive with CCS. The CCS network can be used to rapidly propagate connectivity changes throughout the network, and each switch can then calculate the new routing tables independently. This form of distributed update is attractive from a survivability or reliability viewpoint. Furthermore, the algorithm may be used to adjust the level of tandem traffic through any of the switches, and to produce at least a specified minimum number of alternate routes from each switch to every destination. This algorithm is documented in reference [5].

The modified forward router was exercised (see [5]) as part of an iterative, minimum-cost design algorithm to create routing tables for a candidate 60-node CONUS/CSN AUTOVON. A minimum of four alternate routes was specified at each switch for every possible destination. The tandem traffic constraint was applied at Fairview, Toledo Junction, and Cheyenne Mountain. Design traffic of 4,080 interswitch erlangs (provided by AT&T) was used. Fifty pseudonodes were identified. During each of the eight iterations of the design algorithm, new connectivity, routing, and sizing were accomplished. The following data reflect the results of this exercise and compare the network costs (1975 TELPAK tariff) with a polygrid design:

• CPU time to design each new network (on an IBM 370/155)	69 seconds
• Grade-of-Service	.0704
• Monthly cost of DCEC network	$3,984,000
• Monthly cost of 60-node AT&T polygrid network	$4,250,000

For each design iteration about 15 seconds was required to complete a full modified forward router.

The survivability of the candidate network was compared with the survivability of the above 60-node CONUS/CSN AUTOVON polygrid network designed by AT&T Long Lines. The ability of the two networks to complete National Command Authority (NCA) traffic under switch damage only (i.e., no collateral link damage) was investigated. The survivability index used in the comparison is the ratio of critical calls completed in a damaged network to critical calls completed in an undamaged network. As shown in Figure B-7, the candidate network is no less survivable than the AUTOVON network. The upper limit shown in the figure represents the effect of calls from users homed to destroyed switches; even perfect connectivity and routing could not complete these calls.

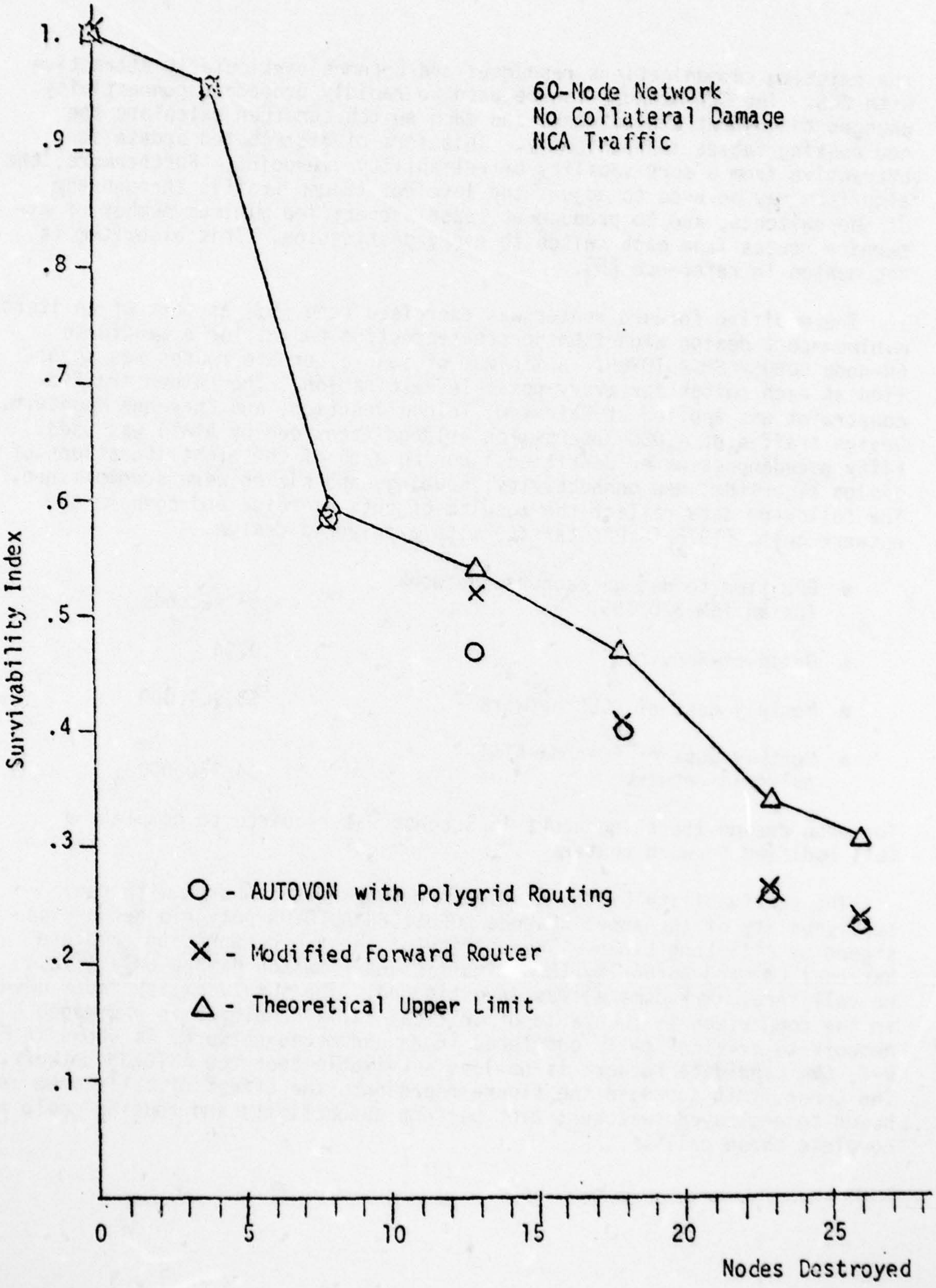


Figure B-7. Survivability Comparison

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[3] DCASEF TC 29-73, "Trunk Signaling and Supervision Network Simulation," August 1973.

[4] DCEC Study (R720), "Common Channel Signaling, Federal 6 Versus TRI-TAC," November 1976.

[5] DCEC TR 26-75, "Modified Forward Routing for CONUS/CSN AUTOVON," September 1975.

Appendix C
Network Design and Economic Analysis

AD-A070 703 DEFENSE COMMUNICATIONS ENGINEERING CENTER RESTON VA F/G 17/2
DESIGN CONCEPTS FOR THE NEXT GENERATION CONUS AUTOVON.(U)
DEC 78 R F DEARDORFF, W P DOTSON, T C HARRIS
UNCLASSIFIED DCEC-TR-18-78 SBIE-AD-E100 231 NL

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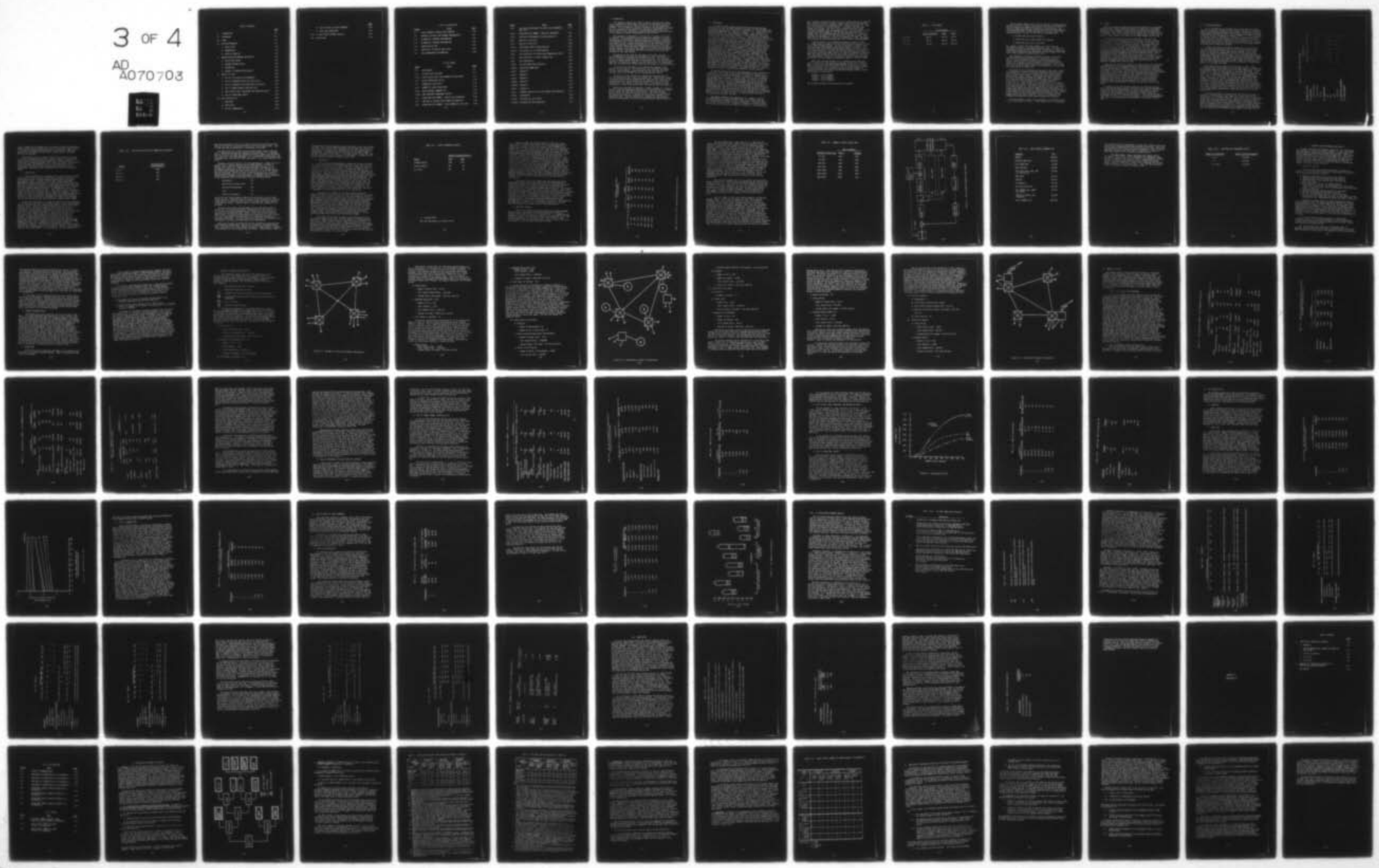

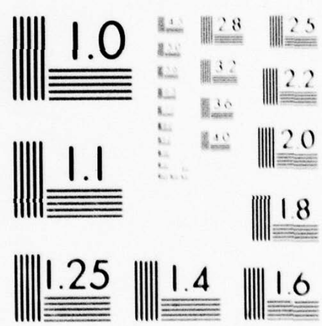

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	C-2
II.	BACKGROUND	C-3
III.	SCOPE	C-7
IV.	COSTING METHODOLOGY	C-8
	1. SWITCH COSTS	C-10
	2. TRANSMISSION	C-13
	3. SATELLITE SERVICES	C-15
V.	NETWORK DESIGN METHODOLOGY AND RESULTS	C-23
	1. ACCESS AREA DESIGN	C-23
	2. BACKBONE NETWORK DESIGN	C-24
	3. ASSUMPTIONS	C-24
	4. AUTODIN II NETWORK DESIGN RESULTS	C-26
VI.	ANALYSIS OF COST	C-35
	1. COST OF THE PRIVATE-LINE APPROACHES	C-35
	2. COST OF APPROACHES USING TELCO FACILITIES	C-35
	3. COST OF APPROACHES UTILIZING SATELLITE SERVICES	C-41
	4. COST OF COMMON CHANNEL SIGNALING (CCS)	C-42
	5. COST OF MULTI-LEVEL PRECEDENCE AND PREEMPTION (MLPP)	C-46
	6. COST OF OPERATIONAL TRAFFIC	C-46
VII.	COST SENSITIVITIES	C-50
	1. INFLATION	C-50
	2. SWITCH COST	C-50
	3. COST OF TRANSMISSION	C-53

		Page
	4. COST OF SATELLITE EARTH TERMINALS	C-55
	5. TOTAL COST UNCERTAINTY	C-55
VIII.	FY 82/92 PERIOD ECONOMIC ANALYSIS	C-60
XIX.	CONCLUSIONS	C-72

LIST OF ILLUSTRATIONS

Figure	Title	Page
C-1	BLOCK DIAGRAM OF TDMA/DA EARTH TERMINAL	C-19
C-2	AUTOVON II PRIVATE LINE NETWORK CONFIGURATION	C-27
C-3	ALTERNATIVE 3 NETWORK CONFIGURATION	C-30
C-4	ALTERNATIVE 6 NETWORK CONFIGURATION	C-34
C-5	ASSOCIATED CCS COST	C-47
C-6	SENSITIVITY TO DIGITAL SWITCH COST	C-52
C-7	COST COMPARISON OF ALTERNATIVES	C-59

LIST OF TABLES

Table	Title	Page
C-I	SCAN CHARGES	C-5
C-II	FY 82/92 PLAN COST MODEL	C-9
C-III	DIGITAL SWITCH COSTS FOR COMMERCIAL APPLICATIONS	C-11
C-IV	SWITCH TERMINATION TARIFFS	C-14
C-V	COMPARATIVE LEASE COSTS	C-16
C-VI	SUMMARY OF TARIFF PROJECTIONS	C-18
C-VII	EARTH TERMINAL HARDWARE COST	C-20
C-VIII	1985 PROJECTED TRANSPONDER TARIFFS	C-22
C-IX	DESIGN AND COST SUMMARY - PRIVATE-LINE APPROACHES	C-36
C-X	1985 COST OF PRIVATE-LINE APPROACH ALTERNATIVES	C-37
C-XI	DESIGN AND COST SUMMARY - TELCO COMMERCIAL FACILITIES	C-38

Table	Title	Page
C-XII	1985 COST OF APPROACHES UTILIZING TELCO COMMERCIAL FACILITIES	C-39
C-XIII	DESIGN AND COST SUMMARY - SATELLITE APPROACHES	C-43
C-XIV	1985 COST OF APPROACHES UTILIZING SATELLITE	C-44
C-XV	ANALYSIS OF CCS COST	C-45
C-XVI	ANALYSIS OF MLPP COST	C-48
C-XVII	OPERATIONAL TRAFFIC DESIGN AND COST	C-49
C-XVIII	COST SENSITIVITY TO INFLATION RATE	C-51
C-XIX	COST SENSITIVITY TO ACCESS AREA TRANSMISSION TARIFF	C-54
C-XX	COST SENSITIVITY TO EARTH TERMINAL COST	C-56
C-XXI	COST UNCERTAINTY	C-58
C-XXII	TEN YEAR TRANSITION STRATEGIES	C-61
C-XXIII	TRANSITION ASSUMPTIONS	C-62
C-XXIV	STRATEGY B	C-64
C-XXV	STRATEGY C	C-65
C-XXVI	STRATEGY D	C-66
C-XXVII	STRATEGY E	C-67
C-XXVIII	STRATEGY F	C-69
C-XXIX	STRATEGY G	C-70
C-XXX	ECONOMIC ANALYSIS OF TEN YEAR TRANSITION STRATEGIES	C-71
C-XXXI	CONCLUSIONS	C-73
C-XXXII	TEN YEAR LIFE CYCLE COSTS	C-74
C-XXXIII	POTENTIAL FOR COST REDUCTION	C-76

I. INTRODUCTION

This appendix presents the technical details regarding the assumptions, computational methodology, and results of the network design and economic analysis studies of the alternatives for the next generation AUTOVON. It is intended for analysts, engineers, and management personnel who are interested in the specifics of the network designs and cost results and for those interested in developing projected budget profiles. It was prepared as supporting documentation for TR 18-78.

This appendix is organized in nine sections, as shown in the table of contents. The Background provides information necessary for understanding why the alternatives were developed, the problems in developing and forecasting costs, and a review of the features of each alternative with regard to cost. Readers interested only in the highlights of this study are encouraged to read the Background and then skip to the Conclusions section. Additional detail regarding the conclusions as well as ten year typical cost profiles are found in the FY 82-92 Period Economic Analysis section. The general conditions and scope of the study are presented in the Scope section.

The details of the study are provided in the middle sections. Costing Methodology discusses the development of costs and tariffs for digital switches, transmission and satellite services. The following section on network design describes in some detail the tools and techniques employed in designing the networks for the alternatives, the assumptions made, and the significant design parameters and values for each alternative.

The detailed costing results are presented and analyzed in the Analysis of Cost section. This section not only discusses the design and cost issues relevant to each alternative, but also the costs for services such as CCS and MLPP and for the operational traffic.

The section on Cost Sensitivities identifies the major areas of cost uncertainty and their impact on network cost. Specifically treated in this section are the cost uncertainties resulting from inflation and technology trends, digital switch cost, transmission cost, and earth terminal cost. The impact of this uncertainity is presented for each alternative in terms of the up-side cost risk and the down-side potential.

Because each alternative represents a network snapshot at a certain period in time and because the alternatives are implementable at different periods within the 1982-1992 planning horizon, the study includes typical transitions over the ten year period. Here, the development of the alternative strategies is merged with identifiable advances at the subscriber level. The cost impacts and a complete ten year economic analysis are discussed in the FY 82-92 Period Economic Analysis section.

II. BACKGROUND

Six CONUS AUTOVON alternatives have been defined and described which could satisfy the CONUS AUTOVON requirements of the mid-1980's and at the same time provide a transition to the DCS III. These alternatives have been categorized into three basic concepts: (a) continue the present approach; (b) take advantage of AT&T's commercial facilities for switching and transmission; and (c) utilize new services expected to be offered in the time frame of interest. The baseline and Alternatives 1, 2, and 5 represent a continuation of the present approach which is a dedicated, switched, private line, leased system for both operational and administrative CONUS AUTOVON traffic. Alternatives 3 and 4 take advantage of AT&T's public facilities in the hope that resource sharing and technological cost/performance improvement in these facilities will reduce the overall cost to the government. In order to develop these two alternatives it is necessary to distinguish between "operational" and "administrative" traffic. Operational traffic represents those users including secure voice subscribers having a requirement for the higher precedence call rankings. The requirements for such users are satisfied by a mini-AUTOVON network similar to today's in concept, but reduced in size from 51 to 10 switches. The requirements for administrative traffic can be met with AT&T's public network, the DDD. Alternative 6 is designed to take advantage of the new satellite services, such as SBS, which are expected to be available in the mid-1980's. This alternative places critical traffic together with some administrative traffic on a thin line terrestrial network. The remaining traffic is routed via a commercial satellite network which emphasizes resource sharing.

If any one issue gave rise to the development of these alternatives, it was cost. This issue exists for both switching and transmission, since the rates by which the government is charged for AUTOVON switches and transmission are subject to imminent and possibly radical changes. The Switched Circuit Automatic Network (SCAN), an offering of the AT&T system since 1961, is the tariff through which DCA leases the AUTOVON switches (47 of the 51 existing CONUS AUTOVON switches are leased through this tariff). Because the projected growth of communications requirements for these switches has not materialized as anticipated, the SCAN arrangements presently in service for both DOD and GSA are underutilized by about 50%, adversely affecting the profitability (as measured by the ratio of net operating earnings to net investment) of the offering, which is -4.5%. Contrast this with, for example, WATS, which has a profitability on the order of 40%.

The Federal Communications Commission, for a number of reasons, has directed AT&T to adjust the SCAN charges in accordance with the Fully Distributed Cost Method 7 (FDC-7) procedures. This would result in a tariff increase of 80%. Because the customers of SCAN (primarily DOD and GSA) would reduce their number of switches to avoid substantial

cost increases, the desired level of return to Bell would not be achieved. Bell therefore proposed a two-step increase such that the desired 9.5% rate of return would be achieved by 1985. Effective October 1977, there was a 20% increase in the SCAN charges. In October 1978 there was another 35% increase. The ratio of net operating earnings to net investment exceeding 9.5%, as provided by FDC-7, will be reached in 1978 through the reduced number of SCAN switches and increased rates. In October 1979, six AUTOVON switches will be eliminated. The cumulative shortfall for the years 1977 and 1978 will be recouped by 1985. This would imply a 3% reduction in the tariff subsequent to 1985, neglecting inflation and the escalating operating costs of older analog equipment.

A short history of the AUTOVON SCAN charges is shown in Table C-I. These rates are based on the AT&T Tariff 260 which applies to 47 of the 51 CONUS AUTOVON switches. The switch termination charge is paid for each access and backbone line which terminates on a switch. The multilevel precedence and preemption (MLPP) charges are also applied on a per termination basis, one for each backbone termination and one for each access termination where there is a line with precedence capability. Note that these charges follow the 20% and 35% increases for 1977 and 1978 respectively. Except for inflation and operation and maintenance escalation, the 1978 charges are expected to remain in effect to 1985.

While the issue with switch cost is increased rates, the issue with transmission is the complete elimination of the TELPAK offering, which is the tariff under which CONUS AUTOVON transmission is leased. AT&T's TELPAK tariff was initiated in 1961 to provide commercial users, including the DOD, with substantial discounts for bulk usage. As originally offered, the tariff provided the following levels of voice frequency(VF) circuit density:

TELPAK A - 12 VF channels
TELPAK B - 24 VF channels
TELPAK C - 60 VF channels
TELPAK D - 240 VF channels.

The discount increases as more channels are procured.

TABLE C-I. SCAN CHARGES

	Dollars/Month		
	Switch Termnation	MLPP	TOTAL
OCT 1976	$46.55	$16.20	$62.75
OCT 1977	$55.85	$19.45	$75.30
OCT 1978	$75.40	$26.25	$101.65

The FCC ordered TELPAK A and TELPAK B offerings eliminated because they were similar to other private services and the rate differential was not justified by competitive necessity or cost savings. The issues of competition and cost distribution continued, exacerbated by the finding that AT&T's TELPAK earnings of 0.3% are far below their targeted earnings of 9.5%. In 1976, the FCC concluded that:

- TELPAK rates were discriminatory
- TELPAK was not a proper competitive response
- Other bulk rates may be justified.

As a result, in early 1977 AT&T withdrew its TELPAK offering. The TELPAK offering is complicated by another issue: the resale of transmission facilities by a third party. Essentially, a third party could procure transmission at substantial savings through TELPAK and resell them, effectively competing with AT&T.

The withdrawal of TELPAK was fought by the users, including the DoD, in FCC hearings and courts. In July 1977, the D.C. Court of Appeals issued an injunction on the discontinuation of TELPAK. This resulted in the continuation of the TELPAK rates to those users of record; TELPAK is denied to new users. Thus, TELPAK now is in a state of limbo. There is no information as to how long this offering will be effective.

The reason for this solicitude on the part of the users is that the alternative to TELPAK is the Multi-schedule Private Line (MPL) tariff, which can cost as much as $3.30 per mile, compared with $0.56 per mile under TELPAK. To appreciate the impact on the DCS of these rate changes, consider for example the recent study by DCEC which concluded that based on TELPAK rates, use of Western Union satellite service would result in an annual savings of $3.4 million. These savings, using the MPL tariff, are reduced to $0.6 million, which implies only a marginal value for the Western Union satellite service. The tariff thus not only affects the dollar value of the system, but also the type of service and vendors to be incorporated into the future DCS. Needless to say, the elimination of TELPAK impacts both the users of and the competitors of AT&T. There is further concern in that if and when TELPAK is withdrawn from the present users, the other terrestrial carriers will probably also withdraw or detrimentally revise their present bulk discounts.

This cost squeeze on the user has resulted in a wholesale examination of alternatives to TELPAK. In this regard, DCA is no exception.

III. SCOPE

The six alternatives under study are not alternatives in an economic analysis sense. Under an economic analysis, alternatives are mutually exclusive in that selection of one implies the exclusion of the others. Furthermore, in an economic analysis, the alternatives are compatible in a time sense; that is, all alternative are defined over the same planning horizon. These elements are absent in the CONUS AUTOVON alternatives.

The AUTOVON alternatives are so defined that selection of one does not preclude the implementation of the others. In fact, the goal of the analysis is not the selection of an alternative but rather the identification of options and decision points. The alternatives thus represent options within the planning horizon of 1982-1992. In the 1982-1985 period, for example, only Alternatives 1, 3, and 4 could possibly be implemented. By 1985, the satellite portion of Alternative 6 could be implemented, whereas the ground portions of Alternative 6 and Alternative 5 may be implemented only in the 1987-1992 period. These time constraints are dictated by DoD policy as well as by service availability. Thus, for example, one alternative in an economic analysis sense may be to continue with the baseline, Alternative 0, until 1985, partially implement Alternative 2 until 1987, and then evolve into subsets of Alternatives 5 and 6 by 1992.

There are many possible strategies for transition over the 1982-1992 planning horizon. It is beyond the scope of this analysis to develop even all the reasonable strategies over the planning horizon using the six AUTOVON alternatives as building blocks. A significant contributing factor here is the current judicial and regulatory uncertainty. Nevertheless, the economic analysis will present sample implementation strategies based upon what seems reasonable at this point in time, using the six AUTOVON alternatives in a building block fashion. As the judicial, regulatory, and economic uncertainties begin to diminish, both new AUTOVON alternatives and new alternatives in an economic analysis sense will surely surface and will modify the results of this limited study.

In terms of a cost and economic analysis, the following sections detail the network design and the costing of each of the six alternatives, discuss the relative effectiveness of these, and present an economic analysis of some reasonable, but of necessity limited, transition strategies over the 1982-1992 planning horizon. While design and cost comparisons of the six alternatives are made, it cannot be overemphasized that these six alternatives are not comparable in an economic analysis sense.

IV. COSTING METHODOLOGY

All six alternatives are designed from tariffed facilities which are now in existence, proposed, or postulated. The specific facilities used in network design and costing are switches, transmission, satellite transponders, and earth terminals. The relationship of these facilities to each of the six alternatives is shown in Table C-II. It can be seen, for example, that for Alternative 2, switching is derived from a new digital switch tariff, and transmission from a combination of AT&T's Digital Data Service (DDS), and the MPL and satellite tariffs. The DDS offering was used solely for the design and cost of the common channel signaling (CCS) transmission network.

In order to accomplish the network design and to develop costs over the 1982-1992 planning horizon, tariff estimates were required which would reasonably reflect what would be charged in this time frame. To simplify the computation process, 1985 was chosen as the technology, design, and cost base year. Thus, costs were developed and networks were designed as if all alternatives were implemented in 1985. In particular, the new digital switches and the satellite earth terminals represent what should be available in 1985. Other tariffed services such as the existing switches and existing transmission offerings were extended to the 1985 time frame.

The projection of existing tariff offerings to 1985 is based on considerations of the trends in previous years together with what can be reasonably expected to materialize in the 1978-1985 period. In the period 1974 to 1978, the WATS tariff has increased about 9.5%. This compares to a commercial telecommunications price index increase of 9.5% also. The ten year trend for 1969 - 1978 of the telecommunications price index is a 9.1% increase. During this ten year period, AT&T's average investment per circuit mile decreased from $18 to $16; this represents an overall annual technological cost improvement of 1.2%. During this ten year period, the average annual rate of inflation for the Federal purchase of goods and services was 6.3%. Thus, telecommunication costs to the customer have increased a total of 60% compared with the average of goods and services during a ten year period characterized by relatively modest technological reductions in the cost to provide transmission.

The period 1978-1985, in contrast with the previous ten years, is expected to produce dramatic cost reductions in both switching and transmission. It is doubtful that the inflationary trend in telecommunications during the past ten years will continue at the approximately 9% annual rate. The combination of technological cost reductions and a slowing inflationary rate is estimated to produce a net annual escalation rate in telecommunication services of 5%. It is also recognized that the inflationary forces may continue to go unchecked and that technological cost performance improvements; while dramatic, may apply only in

TABLE C-II. FY 82/92 PLAN COST MODEL

	Alternatives						
Leased Facilities	0	1	2	3	4	5	6
1. Switching							
Current Switch	X	X					
Digital Switch			X	X	X	X	X
ESS #4				X			
2. Transmission							
DDS		X	X	X	X	X	X
MPL	X	X	X	X	X	X	X
WATS					X		
Satellite	X	X	X	X	X	X	X
3. Satellite Transponder							X
4. Earth Terminal							X

certain segments of the common carrier's network, thereby limiting their overall impact. These considerations tend to sustain the present 9% rate of increase in telecommunication charges to the customer. While the analysis will be based on the 5% factor, sensitivities to a 9% rate will also be explored.

The 5% factor applies to those tariffed services where the total cost impact of emerging technology is small to moderate, namely analog circuit switches and terrestrial transmission. Because satellite transmission is relatvely new with few existing facilities, technological cost improvements are expected to have a more significant impact. Accordingly, for satellite earth stations and transponders, it is assumed that technological cost improvements will offset inflationary trends.

1. SWITCH COSTS

The cost estimate for the commercially available digital switch of Alternatives 2,3,4,5, and 6 is based upon a commercial class 4/5 configuration switch. Several different switches were investigated with regard to cost. As shown in Table C-III, these ranged about $300-$500 per termination for typical commercial applications involving 1000 total lines with 120 trunks. In such commercial applications, over 80% of the originating calls do not go past the switch. This is typical of large commercial PABX applications. In AUTOVON applications, an average of 30% of the calls are local. Thus, given a 120 trunk capacity (costs change as trunk capacity and/ or total lines change), only 171 access lines would be employed. Thus, a 1,000 line commercial application equates to a 300 line switch for AUTOVON application, even though the total switch cost is essentially unchanged. This effectively increases the per used termination cost from an average of $350 to about $1,000.

Research and development is a large cost which must also be factored into the estimated tariff of a new digital switch. A major manufacturer estimates that it takes $25 million in R&D to bring a basic local digital switch to market. While for commercial applications this cost is prorated over a large quantity, R&D costs for any unique government requirements can be extremely large for the limited government quantities. Thus, use of non-commercial switches or switch features will have a major cost impact. MLPP, which is not commercially available, is estimated to cost between $7-$10 million for the total number of switches. Because the total number of terminations does not vary significantly among alternatives, this cost effectively doubles the per termination cost. Thus, a commercial digital switch suitable for CONUS AUTOVON would today cost approximately approximately $2,000 per termination to procure. A Booz-Allen study (DCA Contract 100-76-C-0049) indicates that approximately 31% of the cost of a switch is subject to cost reduction due to improvements in LSI technology. By 1985, applying the

TABLE C-III. DIGITAL SWITCH COSTS FOR COMMERCIAL APPLICATION

Switch	Average Hardware Cost/Termination
Switch A	$386
Switch B	$470
Switch C	$352
Switch D	$297

techniques developed in that study, 31% of the cost can be reduced by 87%. That is, the cost of the switch in 1985 will be 73% of today's cost. Thus, in 1985, the cost per termination is estimated to be $1,500.

The above costs for a digital switch exclude common channel signaling (CCS). Through discussions with commercial manufacturers, it is estimated that CCS will cost an additional $50,000 per switch together with $10,000 per CCS trunk route. For these equipments, it is assumed that technological cost improvement and inflation will offset each other. Thus, these represent 1985 prices.

Currently, no tariff exists or has been developed by a common carrier to provide digital switched services for the CONUS AUTODIN. In order to develop such a tariff for network design and economic analysis, it is necessary to assume that in the 1982-1992 time frame such services will be offered by the common carriers, especially AT&T. It is further assumed that the tariff will reflect the cost to provide the service. In order to convert procurement cost to an annual tariff, maintenance, depreciation, administration, overhead, taxes, and return on investment must be considered. A 0.40 conversion factor was developed using the following values:

Maintenance	.06
Depreciation (10 year life)	.10
Administration/Overhead	.08
Taxes	.04
Return on Investment	.12

The 40% has been checked against known costs and tariffs as well as with common carriers. Considering that the actual tariff charged to the user can exceed carrier expenses and profit by as much as 30%, this factor provides representative results. Sensitivities to a possible 30% increase will be analyzed.

Using the above factor with the $1500 cost per termination yields a monthly cost per termination of $50. Compared with the $143 monthly per termination for an analog AUTOVON switch in 1985, the digital switch is approximately one-third the cost. The No. 4 ESS digital switch handling 30,000 trunks is estimated at $29 monthly per termination exclusive of MLPP. This cost is applicable in Alternative 3 for the services provided the administrative traffic. This cost applies for 1985 under the assumption that inflation will be offset by technological cost improvements.

While under current technology the cost per termination varies with the total number of terminations, a search of the technical literature reveals that in the 1980's time frame, the per line cost of 1,000, 10,000, or 30,000 line switches will not be significantly different. Technology will reduce or

eliminate the existing economies of scale advantage of very large analog switches. Thus, for the CONUS AUTOVON study, the 1985 per line cost of new switches is assumed to be independent of the total number of switch terminations. Considering the fact that most of the CONUS AUTOVON switches have total terminations in a narrowly defined range, 500-1,000, use of a constant cost per termination is reasonable. A summary of the switch termination charges is shown in Table C-IV.

2. TRANSMISSION

The present day CONUS AUTOVON is charged for transmission under the TELPAK tariff which is furnished under court order. This tariff is composed of a monthly cost per circuit mile plus a charge for each line termination or end. In this context, a transmission termination is distinct from a switch termination and more than just the beginning and end point of a DCS line. An end occurs at international boundaries and other points. However, for design and costing purposes, each transmission line, access and backbone, is considered to have two terminations. The current TELPAK charge is $0.56 per mile plus $43 per termination. This rate is expected to be discontinued in the near future, certainly by 1982. Post-TELPAK rates is a hotly contested issue at this time. In terms of developing a 1985 tariff projection, the following are noted: (a) tariffs must reflect the cost to provide the service; (b) the tariff charged for a circuit is based primarily on mileage; (c) the tariff consists of a mileage charge and a fixed charge; (d) the tariff is dependent on the population densities at the end points.

A comparison of charges for various distances based upon present day TELPAK and satellite tariffs and the proposed MPL replacement rates for TELPAK is shown in Table C-V. This table shows the total of the mileage and terminal charges for both line ends. The three different Multi-schedule Private Line (MPL) proposed tariffs depend upon whether both ends, one end, or neither end terminates in one of the 337 AT&T designated high density cities. Most of the CONUS AUTOVON subscribers are in rate center B and the AUTOVON switches in rate center A; hence AUTOVON studies use MPL-AA for the backbone and MPL-AB for the access area. The satellite charges are based upon American Satellite Corporation's filings for service between cities having the approximate mileages shown. These satellite charges currently apply to limited portions of CONUS and exclude local distribution charges.

The comparison in Table C-V shows a very interesting fact. At distances in excess of 500 miles (805 km), MPL-AA is currently cheaper than TELPAK. Where TELPAK provides a significant cost advantage is in the short distance circuits, primarily associated with the access area. Because of this, studies substituting satellite transmission for backbone terrestrial based on TELPAK charges show substantial annual savings of $3.4 million, but when the lower cost MPL-AA is used for the backbone and the higher cost MPL-AB for the local access to the satellite terminal, the savings are reduced to a marginal $0.6M.

TABLE C-IV. SWITCH TERMINATION TARIFFS

Switch	Monthly Charge/Termination 1978	1985
AUTOVON Switch*	$102	$143
Digital Switch*	N/A	50
No. 4 ESS	N/A	29

* -Includes MLPP

N/A -Not applicable, no current tariff.

Because the MPL and satellite tariffs reflect the current alternatives to TELPAK, post-TELPAK tariffs are developed based on these rates. Charges for the access area of CONUS AUTOVON may no longer enjoy the short distance cost advantages currently provided by TELPAK. It is expected that the future short haul (less than 800 miles (1,287 km)) access and backbone transmission charges will remain distance-sensitive, with the backbone-to-access area relative cost as indicated in Table C-V by the proposed MPL-AA and MPL-AB rates. Satellite point-to-point transmission will be more prevelant in the 1980's and will service the CONUS AUTOVON long haul traffic in excess of 800 miles (1,287 km). In excess of 2500 miles (4,023 km), circuit costs are expected to be insensitive to distance, reflecting the fact that satellite transmission costs are primarily fixed rather than variable with distance. The variability portion is more indicative of policy than cost or technical considerations, i.e., competition with terrestrial facilities at shorter distances. The fixed cost nature of satellite transmission dictates high fill which, to achieve, implies quantity discounts. Thus, in the 1980's, backbone long haul transmission will be considerably cheaper than even the present TELPAK or MPL-AA tariffs. This is true in a limited sense for long haul satellite transmission.

The future tariffs, upon which both the network design and the economic analysis are based, reflect the above considerations. Access area transmission is estimated using the proposed MPL-AB tariff inflated to 1985 at 5%. Backbone transmission is based upon the present satellite tariffs and the proposed MPL-AA tariffs. For distances less than 800 miles, the MPL-AA tariff is used, inflated to 1985 at 5%. For distances between 800 (1,287 km) and 2,825 miles (4,545 km), a satellite cost per mile tariff is used which reflects the existing tariff inflated to 1985 at a 5% rate. For distances in excess of 2,825 miles (4,545 km) a fixed charge of $916 is used which is the present tariff of $650 inflated to 1985. The mileage breakpoints were developed from a detailed plot of the tariff data reflected in Table C-V. The projections are summarized in Table C-VI. In this table, the costs reflect the per-mile charge and the charge for both line terminations.

3. SATELLITE SERVICES

The cost of satellite services consists of the space segment, earth terminals, and network control costs required to provide a complete communications service in Alternative 6. It is essentially an estimate of a satellite transmission service to be provided in the 1980 decade by commercial carriers such as SBS. The estimate is made because, while there are presently plans for such a service, tariffs or preliminary cost data are not currently available.

TABLE C-V. COMPARATIVE LEASE COSTS
(DOLLARS/MONTH)

	TARIFF				
Distance in Miles (km)	TELPAK	MPL-AA	MPL-AB	MPL-BB	Satellite
10 (16)	$92	$117	$132	$143	N/A
50 (80)	114	169	223	266	N/A
100 (161)	142	220	290	346	N/A
500 (805)	366	390	460	534	N/A
1000 (1609)	646	590	660	734	330
2000 (3218)	1206	990	1060	1134	487
3000 (4827)	1766	1390	1460	1534	650

Note: MPL charges reflect proposed TELPAK replacement rates.

The anticipated mode of such a service is a TDMA satellite system featuring demand access capabilities and operating in the 12-14 GH_Z band. Essential to this system is a low cost satellite ground terminal operating in the 12-14 GH_Z region with a G/T in the 30-33 dB/^{O}K range. Present earth terminals do not operate in this frequency range and are too costly to permit a station at each user location. New designs are required which by the 1980 time frame will take advantage of technological cost/performance advances to develop an economically viable terminal. An estimate of the cost of such a terminal is developed from an analysis of the major components of an earth station. A block diagram is presented in Figure C-1. In order to satisfy traffic demands, it is anticipated that multiple satellite transponders will be required for some satellite/terrestrial network options. One approach to operating in such a mode is to provide each earth terminal with the capability of receiving from all transponders. This would allow each terminal to be part of the same network although access is through a single transponder. The required incremental receiver chains are indicated by dashed lines in Figure C-1. The interface, control, and processing unit performs the functions of A/D conversion, demand assignment control, TDMA formatting, buffering, and voice activity compression.

The estimated hardware cost for the terminal outlined above is shown in Table C-VII. These estimates are based upon data from a study by Systems Control Inc. (DCA Contract DCA 100-76-C-0060) and from data available in the open literature. The cost for interface, control, and processing has a high uncertainty and could increase as the complexity of the implementing software increases. The estimated cost for this segment is based on handling 50 voice equivalent channels and microprocessing capabilities to accomplish the functions of the unit.

The costs shown in Table C-VII reflect hardware and required software costs. To this must be added costs for test and support equipment (15%), system test and evaluation (25%), site preparation (7%), initial spares (50%), transportation (9%), training (5%), documentation (7%), and program management (10%). Because procurement of large quantities of terminals is expected, a quantity discount of 30% is used. Thus, the commercial equivalent cost of an earth terminal is 1.596 (2.28 X .7) times the hardware cost, or $450,000. For the purposes of this analysis, technological cost performance gains are assumed to offset inflationary cost increases. Hence, the $450,000 per earth terminal reflects a 1985 cost. Using the 40% factor developed previously to convert cost to a tariff, the monthly tariff for an earth terminal is $15,000 in the 1985 period. Because of the uncertainty in actual components to be used and in the projected cost of these components, the 1985 terminal tariff could range from $10,000 to $20,000 per month. These costs apply for a terminal operating with one satellite transponder.

TABLE C-VI. SUMMARY OF TARIFF PROJECTIONS

DISTANCE IN MILES (km)	1985 Cost/Month ACCESS	BACKBONE
10 (16)	$186	$165
50 (50)	$314	$238
100 (161)	$409	$310
500 (805)	$649	$550
1000 (1609)	$931	$465
2000 (3218)	$1495	$649
3000 (4827)	$2059	$916

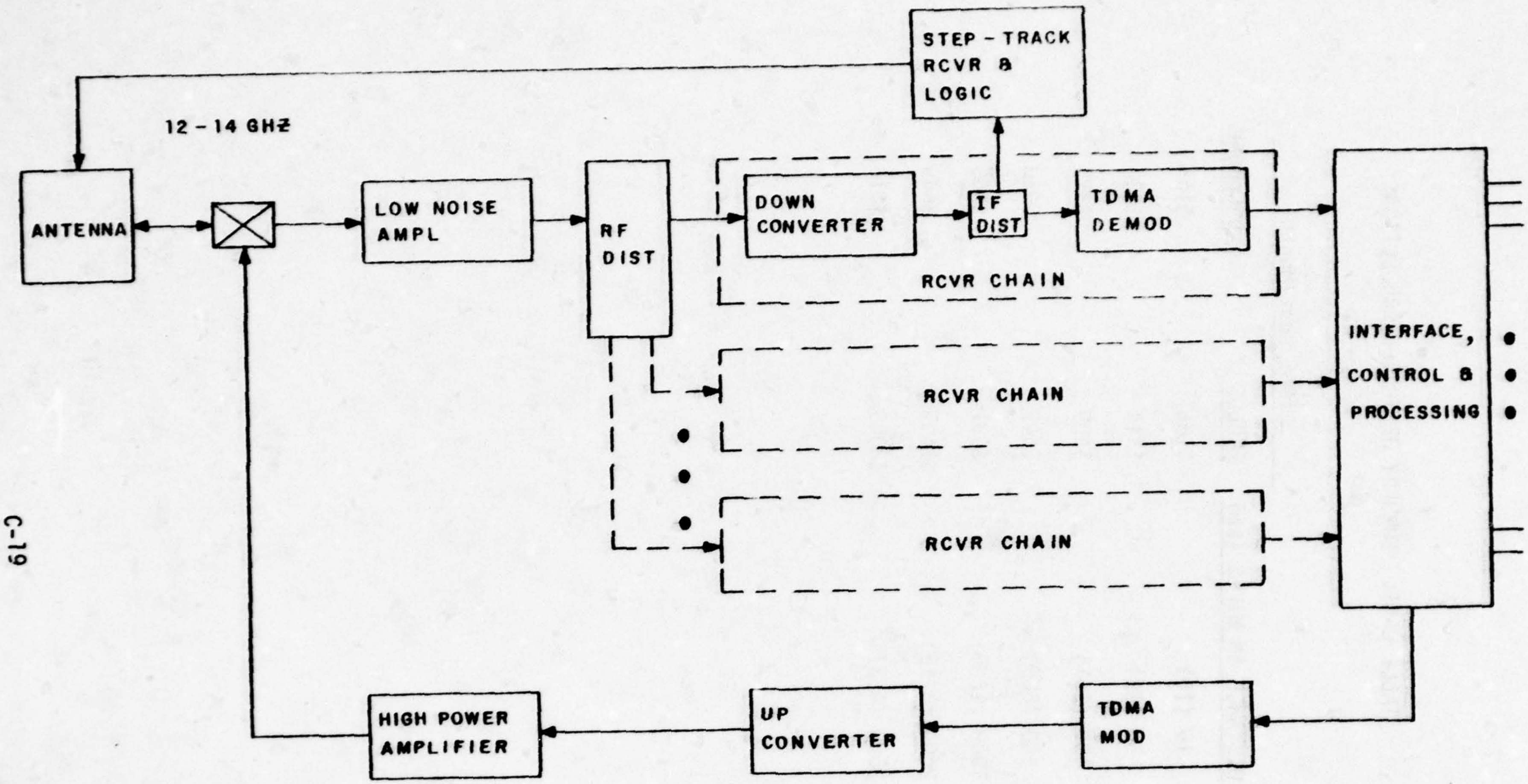

FIGURE C-1. BLOCK DIAGRAM OF TDMA/DA EARTH TERMINAL

TABLE C-VII. EARTH TERMINAL HARDWARE COST

Component	Cost
ANTENNA	$40,000
LOW NOISE AMPLIFIER	$10,000
RF DISTRIBUTION	$2,000
DOWN CONVERTER	$15,000
STEP-TRACK RCVR, LOGIC, AND IF DISTRIBUTION	$10,000
TDMA DEMOD	$20,000
TDMA MOD	$15,000
UP CONVERTER	$15,000
HIGH POWER AMPLIFIER	$80,000
MISC COMMON EQUIP, HDWRE, AND WIRING	$25,000
INTERFACE, CONTROL, AND PROCESSING	$50,000
TOTAL HARDWARE COST	$282,000

In a system of multiple transponders, an additional receiver chain, and control and processing hardware and software are required. These costs are estimated at \$55,000 per additional transponder. Using the factors developed previously, each additional transponder will require an additional monthly tariff of \$3,000 per earth terminal.

The space segment leases, developed from present tariffs, are shown in Table C-VIII. While technology will undoubtedly lower the cost to construct and place into orbit a communications satellite by 1985, inflation can be expected to have a significant adverse impact. The 1985 projection is based on the assumption that the two opposing trends will nullify each other. Thus, the 1985 transponder tariff is assumed to be equal to today's tariff.

TABLE C-VIII. 1985 PROJECTED TRANSPONDER TARIFFS

Number of Transponders	Monthly Charge/Transponder
1 or 2	$142,000
3	$133,000
4 or more	$125,000

V. NETWORK DESIGN METHODOLOGY AND RESULTS

In order to provide valid economic comparisons, all alternatives were designed to the same performance standard. A least cost access area and backbone network was designed which provided a grade of service comparable with the present day AUTOVON (P13). This process entailed the determination of the optimal number and location of backbone switches, cost of homing the subscribers to those switches (access area cost), development of a backbone switch-to-switch traffic requirements matrix, and finally the design of the backbone network including its associated cost.

1. ACCESS AREA DESIGN

The access area design process determined the number and location of the switches which were used in each specific alternative. The following were required as inputs:

- Subscriber geographical locations and the number of AUTOVON access lines associated with each location.
- Candidate switch sites, showing their locations and basic capacities.
- Where applicable, the cost of adding additional terminations at a switch. This was generally of the form of a cost for a module consisting of 50 terminations using the costs shown in Table C-IV.
- Incremental backbone network transmission cost which would be incurred by the addition of a switch.
- The cost of transmission (tariff). This is expressed as a function of mileage and a terminal cost for each end of the transmission line. Representative values are shown in Table C-VI.

A heuristic approach known as an "ADD" algorithm was used to select switching sites. The access area design program is initialized by determining the "center of mass" (COM) of all the subscriber locations weighted by the number of lines, selecting the candidate switch closest to this center of mass, and computing the cost of homing all subscribers to this candidate switch. For each subscriber location, the current homing (i.e., switch identification) and cost of homing is retained. The ADD algorithm begins at this point and proceeds generally as follows:

(1) For each candidate switch location, I, examine each subscriber location, k, to determine whether an access transmission savings could be realized by rehoming subscriber k to switch I rather than retaining the present homing.

(2) Sort the subscriber locations in descending order of savings, and temporarily load the switch (or switch module in the case where the switch is already part of the network) with the locations that

save the most money until the switch (module) has reached its termination capacity. This determines the "raw" savings. The net savings which would be realized by adding this switch (or switch module) would be the "raw" savings less the cost of backbone transmission (zero for a module) which would be required to interconnect this switch with the remainder of the backbone network. The switch with the greatest positive savings would be added to the network, the homing and homing costs of affected subscribers would be revised, and the ADD procedure would start again at the initial step. This iterative process continues, adding one switch or switch module at each iteration and stopping when no further savings can be realized. At this point, if there is insufficient termination capacity in the selected switches to terminate all subscriber lines, switches (modules) would be added (at a loss) until all subscribers are accommodated.

(3) The output of this program provides the total network access cost as well as the number of switches which were used, and the homing of all subscriber locations. The switches selected, the homing of the subscriber locations, and subscriber-to-subscriber traffic data (program input) is then used to generate the backbone switch-to-switch traffic requirements matrix. The switch location file and the backbone traffic matrix are then used as inputs to the backbone network design program which is described in the following paragraphs.

2. BACKBONE NETWORK DESIGN

The backbone design was based upon the use of the DCEC "KATZ" model. This model determines the connectivity, sizing, routing, cost, and network grade-of-service (GOS) for a backbone network. The inputs required are the switch locations, the switch-to-switch traffic requirements, desired link blocking, and the cost (tariff) of transmission and switching. This model, like the access design program, employs an iterative design process except that in this case, the network is initialized as fully connected. At each iteration a routing table is generated by the program and the traffic is loaded onto the network using the routing table. The link blocking determines the amount of traffic employing primary paths as well as overflowing onto the alternate routes. Once the traffic has been loaded onto the network, the trunks are sized for their offered load. Links which are not cost-effective are eliminated, a new routing table is generated, the traffic is again loaded onto the network, and the trunk groups are resized. Again, links are removed which are not cost-effective, and the procedure continues until no further savings can be realized, at which time the performance (GOS) of the network is determined, and the procedure stops.

3. ASSUMPTIONS

Certain simplifying assumptions were made to the subscriber data base prior to deriving the network designs. These are discussed in the following paragraphs.

A small number of overseas locations (e.g., Ramstein, GE) have access lines terminating directly on CONUS AUTOVON switches. Because of the long and costly access lines involved, these locations could unduly influence the switch selection process toward switches near the coasts. In an attempt to reduce this effect, the coordinates of all overseas subscribers were changed to approximate CONUS international cablehead locations.

The Canadian subscribers were treated as if they were collocated with their nearest Canadian AUTOVON switch. The present Canadian AUTOVON switches were then treated as subscribers to CONUS AUTOVON, and all intra-Canadian traffic was ignored,accounting for the difference in the erlang load stated in Appendix A. This was done in an attempt to provide a more valid cost comparison among the various alternatives since:

- The number and location of Canadian switches appear to be strongly influenced by factors other than cost.

- Certain of the tariff structures (i.e., WATS, or No. 4 ESS toll network) do not appear to be applicable to the Canadian portion of AUTOVON.

An estimate of incremental backbone transmission cost is one of the required inputs to the access area design program. This value is used in the access area design in deciding whether or not the addition of a switch is economically justified. If another switch is added to the backbone network, additional connectivity must be provided (at additional cost) in order to effectively utilize the new switch. Previous work done by DCEC indicates that approximately 50 backbone channels with an average length of 700 miles (1,126 km) each are added for each additional switch. This formed the basis for an incremental cost of $32,430 per month per additional switch. This cost was used in the design of all alternatives except when the network served only the critical subscribers and in the selection of ground terminal locations in Alternative 6. For the operational traffic, the incremental cost was scaled linearly in proportion to the ratio of critical traffic to total traffic. For Alternative 6, the incremental cost was zero since the space segment capacity remained relatively constant regardless of the number of ground terminals used.

4. AUTOVON II NETWORK DESIGN RESULTS

The alternative network designs will be summarized in the following sections. Any unique features or constraints will be discussed as part of that alternative. Additionally, a much simplified schematic drawing will be provided showing the general network topology of each alternative. The following symbols will be used in those drawings:

O - Administrative subscriber location

X - Operational Subscriber location

□ - AUTOVON switch (for use by administrative subscribers)

⊠ - AUTOVON switch used by both operational and administrative subscribers

4 - No. 4 ESS switch

 - Satellite ground terminal.

The baseline, Alternative 0, represents AUTOVON as it would exist if no changes were made to the network except for the removal of six switches (Yakima, Stevens Point, Norway, Dover, Ennis, and Colorado Springs) which is planned for approximately October 1979. The network would appear as shown in Figure C-2. In this case, each switch serves both administrative and operational subscribers and the backbone carries both administrative and operational traffic. All remaining CONUS switches (45) were used in this design. The results of this design are as follows:

- Access design
  - Number of Access lines - 16,701
  - Total Access Channel Miles - 1,593,159
  - Average Access Line Length - 95 miles (153 km)
- Backbone Design (Network GOS = P13
  - Number of IST's - 913
  - Total Channels - 7460
  - Total Channel Miles - 5,013,223
  - Average IST Length - 672 miles (108/km)
- Total Number of Switches - 45.

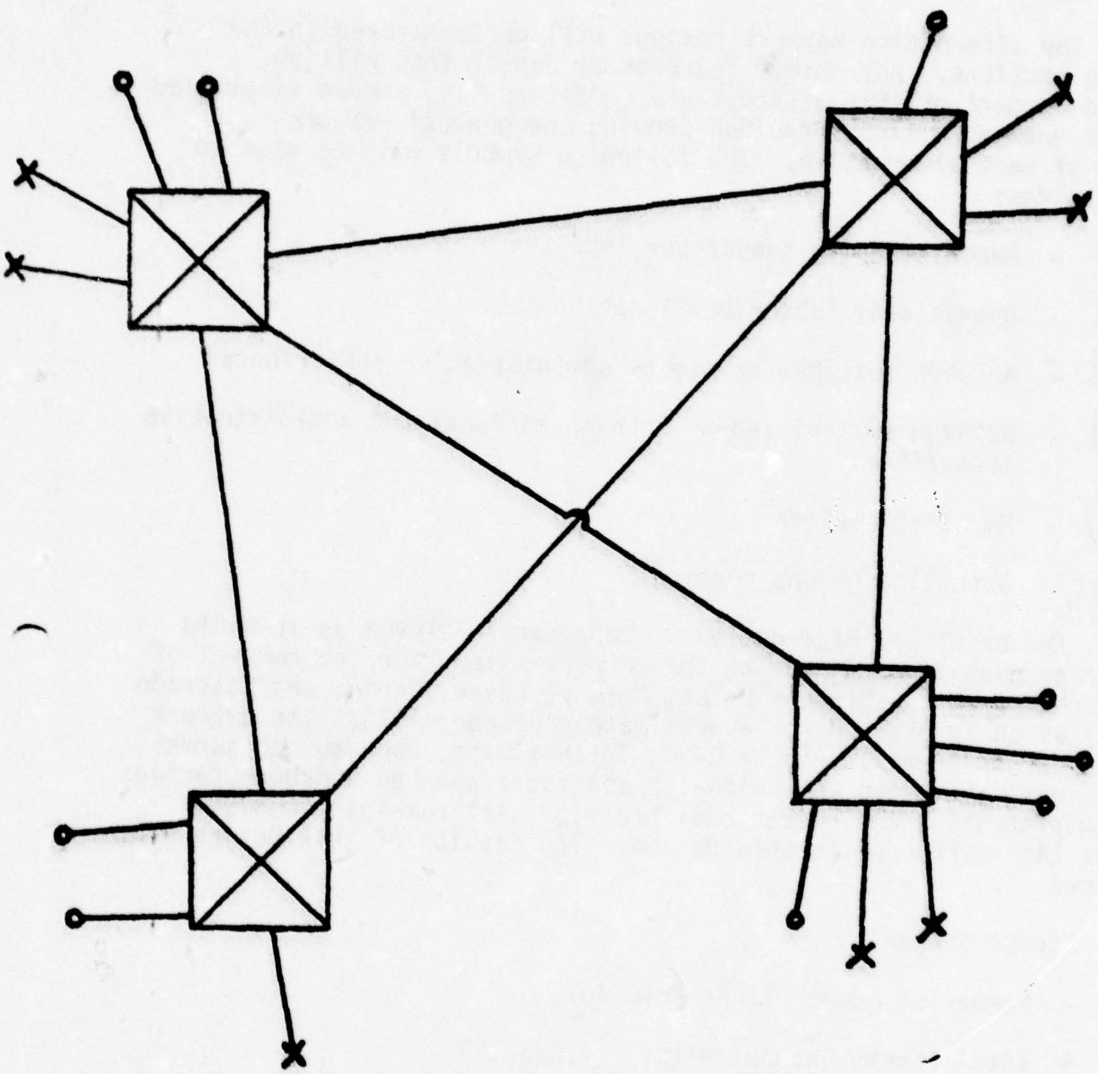

Figure C-2. AUTOVON II Private Line Network Configuration

Alternative 1 assumes that all subscribers, administrative as well as operational, will be served by a single AUTOVON II network. The network configuration is as shown in Figure C-2, except that CCS is provided. The candidate switches for this network were the 45 CONUS AUTOVON switches described for the baseline alternative (i.e., those sites which will remain after October 1979). Only 35 of these 45 switches were selected for the optimum design. The switch capacities used were those of the present CONUS AUTOVON switches, and no additional termination modules were allowed. The analysis resulted in the following design:

- Access Design
  - Number of Access Lines - 16,701
  - Total Access Channel Miles - 1,662,159
  - Average Access Line Length - 100 miles (161 km)
- Backbone Design (GOS = P12)
  - Number of IST's - 587
  - Total Channels - 7,141
  - Total Channel Miles - 4,927,316
  - Average IST Length - 690 miles (1,110 km)
- Total Number of Switches - 35.

The network configuration for Alternative 2 is the same as that shown in Figure C-2, with all subscribers being served by a single AUTOVON II network. The 51 candidate switch sites used in this alternative included the 45 sites used in Alternative 1, as well as the sites of the six switches which are scheduled for removal (Yakima, Stevens Point, Norway, Dover, Ennis, and Colorado Springs). The switch costs used were based upon new digital switch costs of $50.00 per termination for modules of 50 terminations each. The switch capacities were initially set at 200 with the exception of switches in areas of extremely high subscriber density, such as the Washington area, where the capacities were initialized at 800 switch terminations. Switch capacity was allowed to increase in increments of 50 terminations. The resulting access area and backbone designs are summarized below:

- Access Design
  - Number Access Lines - 16,701
  - Total Channel Miles - 1,598,346
  - Average Access Line Length - 96 miles (154 km)

- Backbone Design (GOS = P12)
  - Number of IST's - 398
  - Total Channels - 6,759
  - Total Channel Miles - 4,691,407
  - Average IST Length - 694 miles (1,117 km)
- Total Number of Switches - 29.

The configuration of Alternative 3 is shown in Figure C-3. The administrative subscribers are homed to new digital switches which are located at some subset of the present AUTOVON sites. These switches, in turn, are provided with a trunk to their nearest No. 4 ESS switch. Administrative traffic, thus, traverses a trunk to a No. 4 ESS switch, through the AT&T toll network, and exits through another No. 4 ESS-to-VON switch trunk. For purposes of cost comparison, the VON-No. 4 ESS trunks were sized for P045 blocking, and an No. 4 ESS backbone network was designed, and costed for P045 GOS in order to provide an overall P13 grade-of-service for the administrative traffic. The cost of the backbone No. 4 ESS network was computed using the same tariff (combination of MPL and Satellite) as used in all administrative backbone network designs. This probably represents a pessimistic design, since a "virtual" channel through the No. 4 ESS network could take advantage of techniques such as using spare capacity due to non-coincident busy hours in the AT&T plant. The operational subscribers access a subset of the new digital switches which are then interconnected to provide a dedicated backbone network to serve their needs. The resulting designs are summarized below:

(a) Administrative Subscribers

- Switching
  - Number of VON Switches - 26
  - Number of No. 4 ESS Utilized - 21
- Access (accessing New Digital VON Switches)
  - Number of Access Lines - 12,171
  - Total Channel Miles - 1,788,808
  - Average Access Line Length - 147 miles (237 km)
- VON No. 4 ESS Trunking
  - Number of VON No. 4 ESS Channels - 8,382
  - Total Channel Miles - 269,900

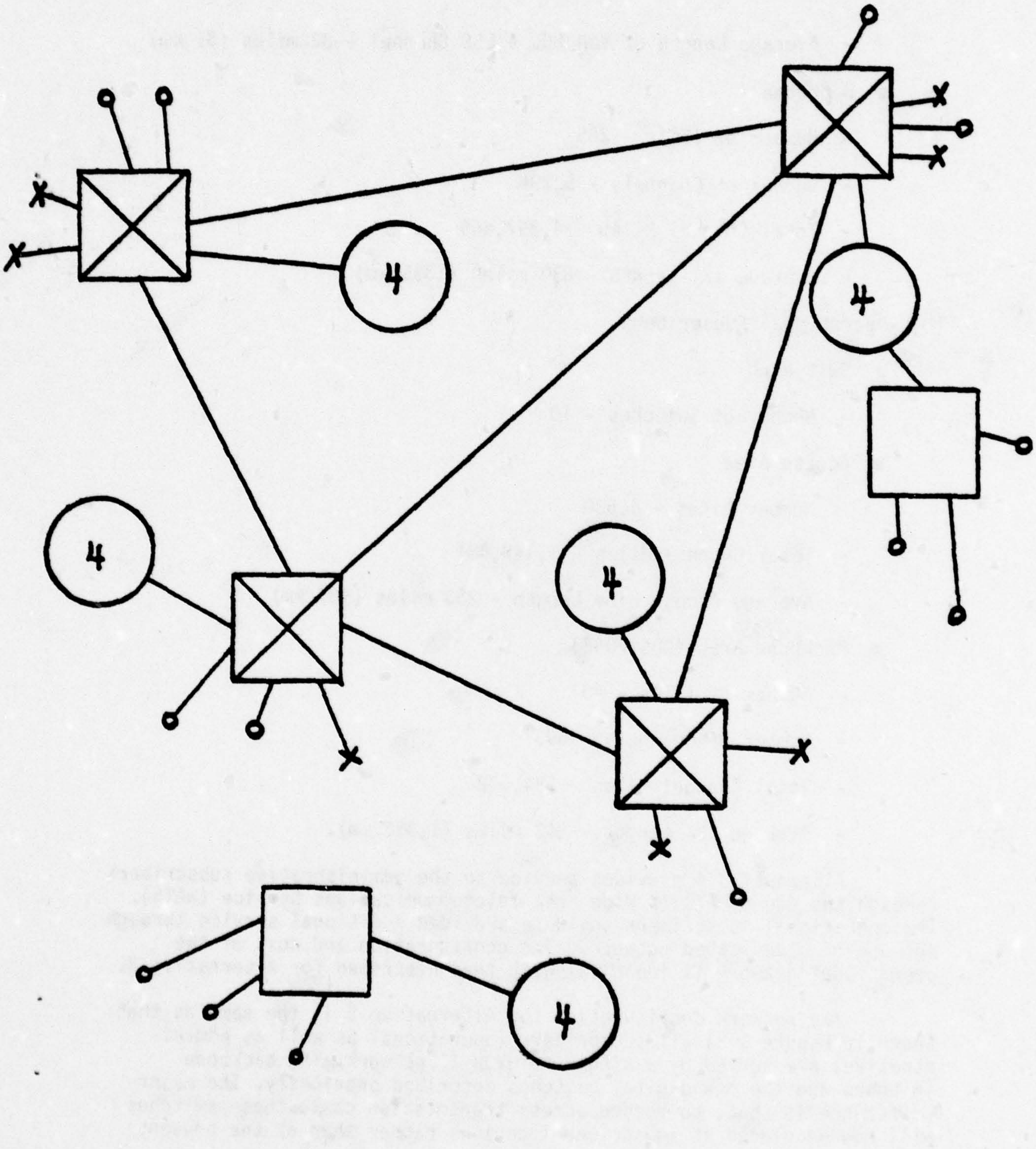

Figure C-3. Alternative 3 Network Configuration

- Average Length of VON NO. 4 ESS Channel - 32 miles (51 km)

- Backbone
  - Number of IST's - 205
  - Number of Channels - 5,296
  - Total Channel Miles - 4,397,465
  - Average IST Length - 830 miles (1335 km)

(b) Operational Subscribers

- Switching
  - Number of Switches - 10
- Access Area
  - Number Lines - 4,530
  - Total Channel Miles - 1,149,481
  - Average Access Line Length - 253 miles (407 km)
- Backbone Area (GOS=P043)
  - Number of IST's - 40
  - Number of Channels - 693
  - Total Channel Miles - 584,372
  - Average IST Length - 843 miles (1,356 km).

Alternative 4 provides service to the administrative subscribers through the use of AT&T's Wide Area Telecommunications Service (WATS). The operational subscribers would be provided additional service through the use of a dedicated network. The configuration and cost of the operational network is identical with that described for Alternative 3.

The network configuration for Alternative 5 is the same as that shown in Figure C-2; all subscribers (operational as well as administrative) are served by a single AUTOVON II network. The backbone switches are the new digital switches described previously. The major difference is that, to reduce access transmission cost, these switches will now be placed at subscriber locations rather than at the present

AUTOVON switch sites. Note that the tariff assumptions used give an additional advantage to this alternative as well as to the operational network B. Collocated subscribers (i.e., subscribers within 1 mile (2 km) of the switch) are assumed to use base transmission facilities for accessing the switch. Thus, savings of two transmission termination charges are made for every collocated subscriber, in addition to savings accrued through shortening the commercial transmission segment of the access area design. One hundred thirty four subscriber locations are used as candidate switch sites. These sites represent the subscriber locations with the greatest number of access lines as well as smaller locations chosen to provide geographic diversity. Of the 134 candidate switch sites, 82 are selected as AUTOVON II switches. The resulting network is summarized below:

- Number of Switches - 82
- Access Design
  - Number of Access Lines - 16,701
  - Total Channel Miles - 611,433
  - Average Access Line Length - 37 miles (60 km)
- Backbone Network (GOS=P 13)
  - Number of IST's - 1,628
  - Total Channels - 9,151
  - Total Channel Miles - 5,343,241
  - Average IST Length - 584 miles (940 km).

Alternative 6 makes use of satellite demand access and numerous small ground terminals to provide long-haul administrative communications. A terrestrial network using small digital backbone switches at subscriber locations provides primary communications for the operational subscribers as well as short distance communications for administrative users. Ground terminals are generaly collocated with backbone switches. Figure C-4 depicts the topology of this alternative.

All operational subscriber access lines terminate on terrestrial switches. Access lines from each administrative subscriber location are terminated on both a ground terminal and on a terrestrial switch in the same ratio as that of the "long-haul" and "short-haul" traffic being generated by that location. An exception is made to ensure that each subscriber has at least one access line terminating on a backbone switch.

The total system cost of this alternative is then a function not only of the number and location of the switches and ground terminals with associated costs for transmission (terrestrial and space segment), but also in this case the definition of "long-haul" traffic. A different minimum cost network could be designed at every point corresponding to the amount of administrative traffic carried by satellite. Therefore, several minimum cost networks were designed corresponding to mileage breakpoints beyond which administrative traffic would be carried by satellite. This was done to determine the satellite/terrestrial traffic mix which would provide the lowest total system cost. Based upon the transmission, switching, and ground terminal costs used, the minimum cost system for this alternative can be achieved at the point where approximately 70% to 80% of administrative traffic is carried by satellite. Thus, network design for a mileage breakpoint of 300 miles (70% administrative traffic carried on satellite) is summarized below:

(a) Satellite Network

- Transponders - 3
- Earth Terminal Access Lines - 8,867
- Earth Terminal Access Channel Miles - 561,113
- Average Earth Terminal Access Line Length - 63 miles (101 km)
- Earth Terminals - 42

(b) Terrestrial Network

- Access Design
  - Number Access Lines - 7,834
  - Total Channel Miles - 352,610
  - Average Access Line Length - 45 miles (72 km)
- Backbone Design
  - Number of IST's - 486
  - Total Channels - 2,996
  - Total Channel Miles - 954,109
  - Average IST Length - 318 miles (512 km).

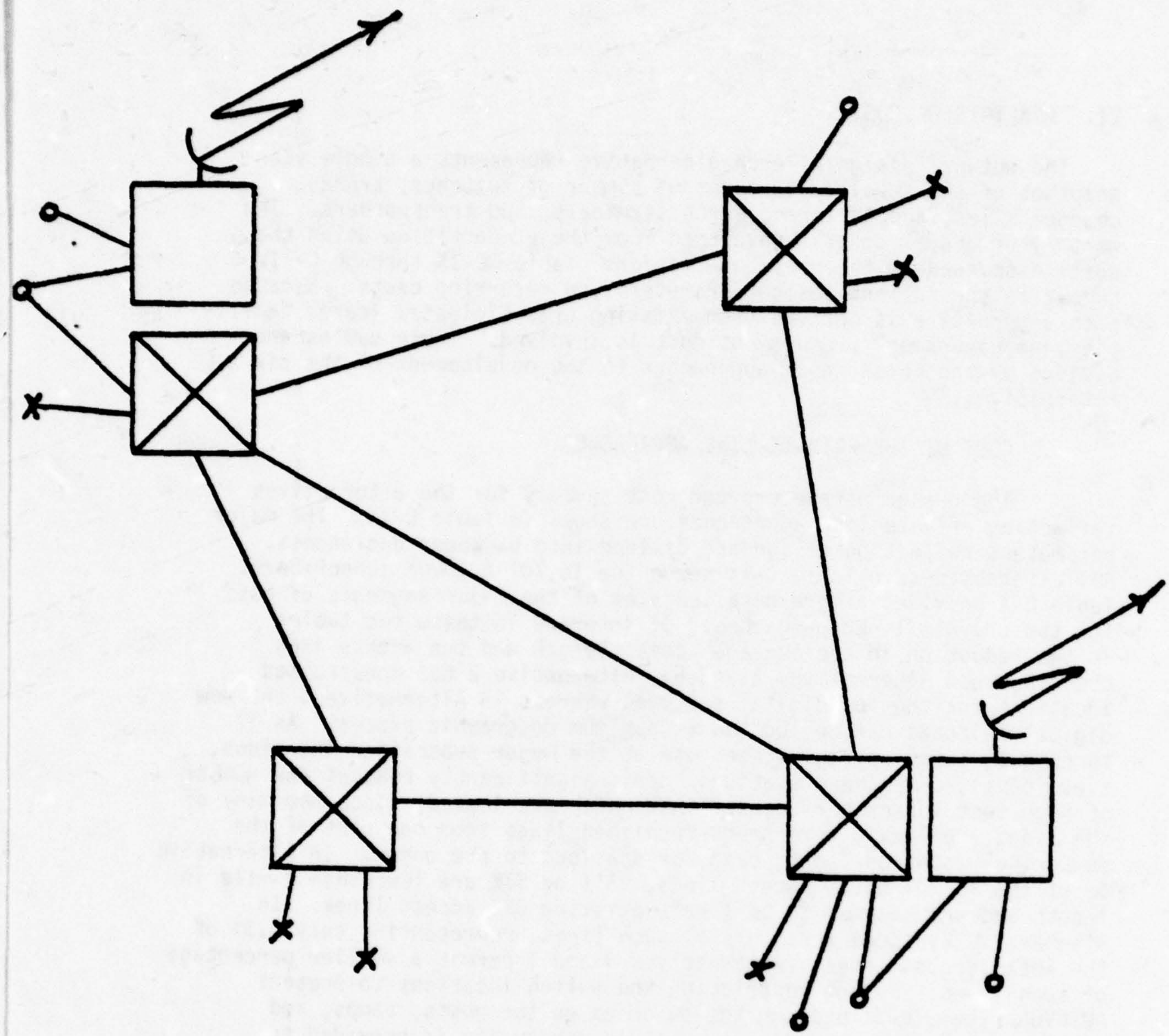

Figure C-4. Alternative 6 Network Configuration

VI. ANALYSIS OF COST

The network design of each alternative represents a single year snapshot of the topology in terms of number of switches, trunks, channel miles, access lines, earth terminals, and transponders. The monthly or annual cost is developed from these quantities using the costs discussed in the previous section. Tables C-IX through C-XIV summarize the salient design parameters and recurring costs. Because each alternative is derived from existing or anticipated leased facilities, no government procurement cost is involved. These tables are divided by the three major approaches to the development of the six alternatives.

1. COST OF THE PRIVATE-LINE APPROACHES

The design parameters and cost summary for the alternatives reflecting private line approaches are shown in Table C-IX. The major parameters reflecting design are divided into backbone and access. All alternatives in Table C-IX serve the 16,701 AUTOVON subscribers. Table C-X provides a more detailed view of the major segments of cost for the private line approaches. Of interest in these two tables is the reduction in the average access length and the access area costs between Alternatives 2 and 5. Alternative 2 has constrained locations for the new digital switches whereas in Alternative 5 the new digital switches can be located at optimum geographic places. As it turns out, these optimum places are at the major subscriber locations, i.e., posts, camps, and stations. This significantly reduces the number of high cost subscriber access lines which are leased, since now many of the lines are local, government-furnished lines from one part of the subscriber location (post, camp, or station) to the other. In Alternative 5, of the 16,701 total access lines, 9541 or 57% are less than 1 mile in length and are assumed to be local, existing GFE access lines. In Alternative 2, there were only 51 such lines, representing only 0.3% of the total access lines. Alternatives 0 and 1 permit a smaller percentage of such lines. By not restricting the switch locations to present AUTOVON sites, and locating the switches on the posts, camps, and stations where the subscribers are, an opportunity is provided to significantly reduce access area costs by a factor of 2.5 while only increasing backbone transmission by 10%. This appears to be a cost effective direction for implementing future private line switched networks. If CCS is commercially available and cheaply implemented within the digital switch, this approach as exemplified by Alternative 5 becomes even more attractive.

2. COST OF APPROACHES USING TELCO FACILITIES

Two alternatives were derived based on making maximum use of the public TELCO facilities. Alternative 3 employs the No. 4 ESS switches as a gateway to the DDD network whereas Alternative 4 employs

TABLE C-XI. DESIGN AND COST SUMMARY - TELCO COMMERCIAL FACILITIES

	Alternative 3		Alternative 4	
	Admin	Critical	Admin	Critical
Design				
Subscribers Backbone	12,171	4530	12,171	4530
Switches	26	10	N/A	10
Trunks	205	40	N/A	40
Channels	5296	693	N/A	693
Ave. Length (Miles/km)	830/1,335	843/1,356	N/A	843/1,356
Access				
Channel Miles	1,788,808	1,149,481	N/A	1,149,481
Ave. Length (Miles/km)	147/237	253/407	N/A	253/407
VON-ESS				
No. 4 ESS Switches	21			
Channel Miles	269,900	N/A	N/A	N/A
Ave. Length (Miles/km)	32/5/	N/A	N/A	N/A
Cost/Month (1000)	$10,914	$3,059	$12,624*	$3,059
Cost/Year (1000)	$130,968	$36,708	$151,488	$36,708

*Net WATS Cost

TABLE C-X. 1985 COST OF PRIVATE-LINE APPROACH ALTERNATIVES
(Thousands of Dollars per Month)

	Alternatives			
	0	1	2	5
Access Area	$5,878	$5,954	$5,841	$2,354
Switching	4,532	4,441	1,545	1,860
Backbone	3,605	3,498	3,313	3,982
CCS	N/A	2,504	876	3,008
Monthly Total	$14,015	$16,397	$11,575	$11,204

TABLE C-XI. DESIGN AND COST SUMMARY - TELCO COMMERCIAL FACILITIES

	Alternative 3		Alternative 4	
	Admin	Critical	Admin	Critical
Design				
Subscribers Backbone	12,171	4530	12,171	4530
Switches	26	10	N/A	10
Trunks	205	40	N/A	40
Channels	5296	693	N/A	693
Ave. Length (Miles/km)	830/1335	843/1356	N/A	843/1356
Access				
Channel Miles	1,788,808	1,149,481	N/A	1,149,481
Ave. Length (Miles/km)	147/237	253/407	N/A	253/407
VON-ESS				
No. 4 ESS Switches	21			
Channel Miles	269,900	N/A	N/A	N/A
Ave. Length (Miles/km)	32/5/	N/A	N/A	N/A
Cost/Month (1000)	$10,914	$3,059	$12,624*	$3,059
Cost/Year (1000)	$130,968	$36,708	$151,488	$36,708

*Net WATS Cost

TABLE C-XII. 1985 COST OF APPROACHES UTILIZING TELCO COMMERCIAL FACILITIES
(Thousands of Dollars per Month)

	Alternative 3			Alternative 4	
	Admin	Operational	Total		
Access	$4,708	$2,111	$6,819	WATS	$13,860
Switching	1,060	310	1,370		
Backbone		512	512	Operational	3,059
CCS	64	126	190		
VON-ESS	1,727		1,727	Existing WATS	(1,236)
ESS-BB	2,805		2,805		
No. 4 ESS	550		550		
Monthly Totals	10,914	3,059	13,973	Monthly Total	15,683

WATS for direct entry into the DDD. Table C-XI presents the salient design parameters and the recurring costs of these two alternatives. A detailed cost breakout is shown in Table C-XII. Each alternative carries its operational traffic over ten new digital switches located at the present AUTOVON sites. Designs for operational traffic where the switch locations are unconstrained yield a 17-switch solution with a total monthly cost of $2,578,000, or 16% less in cost. As with Alternative 5, low cost digital switches located optimumly yield designs characterized by more switches at a lower total systems cost.

The DDD facilities utilized in Alternative 3 consist of the 21 No. 4 ESS switches, the AUTOVON switch to No. 4 ESS trunk lines, and the No. 4 ESS backbone network. Since no tariff presently exists to utilize these facilities in the manner specified for Alternative 3, the costs were based upon projected No. 4 ESS costs and the projected MPL tariff for a dedicated network using these facilities. Thus, these costs reflect that of a dedicated, private line switched network, implying full time utilization. Alternative 3 specifies a service and thus does not require specific or dedicated transmission paths. The distinction between these in terms of cost is not clear at this time. Because of regulatory uncertainties, and a competitive situation in which a third party can resell transmission facilities in competition with AT&T, the realization of a tariff required by Alternative 3 may present problems. Thus, a dedicated, private line implementation as costed is as realistic a cost assessments practical at present.

Alternative 4 also requires a tariffed service which does not presently exist. It requires a Wide Area Telecommunications Service (WATS) limited to the DOD community. (The WATS is a special bulk-rate arrangement for directly dialed station-to-station toll telephone service.) Whether or not this is feasible for AT&T to implement is not addressed here. However, in lieu of such a tariff, the actual WATS tariff projected to 1985 using a 5% compound inflation rate was used for costing.

The 48 conterminious states are divided into 58 WATS service areas. The geographical coverage of WATS from any one of these service areas is determined by the band of service. Each service area has from one to five bands for the 48 states. Service to Alaska and Hawaii and to Puerto Rico, St. Thomas, and St. John requires the use of bands six and seven. The service applies for interstate calls only and is offered on either a measured time or a full business day basis. The service is further divided according to outward or inward, with inward being represented by the familiar "800" number. With regard to Alternative 4, outward WATS is used.

It is not possible to compute the cost of WATS at each location within the 58 CONUS service areas, since information on precise subscriber

location and outward traffic by destination would be required. Such data are not completely available. In order to develop a cost estimate for WATS, an average location is assumed to be located in Virginia which has a band 5 tariff typical of 24 of the 58 service areas. Using the total of 4,700 erlangs and 12,171 administrative lines, the average location has 23 lines and 8.8 erlangs of busy hour traffic. In order to compute a cost, both the distribution of traffic by band and the total number of lines required must be determined. Using Virginia as a basis, it was determined that Band 1 approximated distances up to 300 miles (483 km); Band 2, 300-600 miles (483-965 km); Band 3, 600-900 miles (965-1,448 km); Band 4,900-1,500 miles (1,448-2,414 km); and Band 5, in excess of 1500 miles (2,414 km). The erlang traffic distribution by distance is known and is given in Appendix A of this report. Using that information, that 28% of the traffic is in band 1, 21% in band 2, 18% in band 3, average location for a full business day service can be computed from this information. This weighted, average WATS tariff is $1,429 per month per WATS line. Using the Erlang B function for a P045 GOS and 23 subscribers, the total number of WATS lines required per location is 13. For each of the 23 subscribers, 13 WATS lines are required, or for the 12,171 subscribers, 6,879 lines are needed. The total monthly cost is $13,860,000 inflated to 1985 at 5%.

Because many subscriber locations already have a WATS service, an incremental WATS cost is estimated. The data to develop this incremental cost are extremely hard to obtain. Because of consolidated billing, identifying actual locations which have WATS may not be possible. As a guideline for estimating the impact of existing WATS cost, note that the Pentagon switch at present has 490 subscriber access lines and 38 WATS lines, mostly band 1. Based on this limited sample, it appears that approximately 8% of the subscribers presently have a direct WATS access. It is estimated that, of the 12,171 administrative subscribers, 974 of them already have access to WATS. This is used as the basis for computing an offsetting cost for these existing lines. Thus, the WATS cost of Alternative 4 represents a net incremental cost. Since WATS can access both DoD and commercial telephones, the cost of this alternative represents a service more encompassing than the existing AUTOVON service. Cost offsets resulting from this expanded service have not been estimated or accounted for in this analysis.

3. COST OF APPROACHES UTILIZING SATELLITE SERVICES

Alternative 6 is based upon taking advantage of future satellite services, such as SBS, which are expected to materialize in the 1980's. Three options within Alternative 6 are developed, based on an analysis of distance versus traffic. The pertinent design parameters and recurring costs are summarized in Table C-XIII. A detailed cost summary is provided in Table C-XIV. At 300 miles (483 km) or more, 53% of the subscriber traffic, which is 70% of the total administrative traffic, will go over satellite. Forty-seven percent of the total traffic, including all of the operational traffic, is routed over terrestrial

facilities. For all traffic routed distances in excess of 1,200 miles (1,931 km) or more, 19% of the total subscribers which represents 24% of the administrative traffic can be served with the satellite service, whereas 81% are served through terrestrial facilities.

In Table C-XIII, costs are shown for both the terrestrial and space facilities. The terrestrial access costs are for access to the terrestrial AUTOVON digital switches. Access to the satellite earth stations are included in the total satellite network cost. Earth station access cost was $1,884,000 per month for the 42 earth stations in the 300 mile (483 km) breakpoint, $1,653,000 per month for the 30 stations, and $972,000 per month for the 17 earth stations. The space facilities costs reflect the 1985 estimate of the total satellite service for the three options analyzed.

4. COST OF COMMON CHANNEL SIGNALING (CCS)

In all but the alternatives derived from the DDD network, i.e. Alternatives 3 and 4, the cost for associated CCS is significant, ranging from 8% to 27% of the total recurring cost. Table C-XV presents for the six alternatives both the cost for CCS and this cost as a percentage of the total recurring alternative cost. The cost for CCS consists of the hardware cost at the switch together with the transmission cost for the CCS channels, which are costed at the 4.8 kb/s tariff inflated to 1985 at an average rate of 5%. In Alternative 1, the hardware costs are developed from an analysis of the existing AUTOVON switch configurations and represent modifications to these existing analog switches. In the other alternatives where a digital switch is employed, the CCS cost consists of a software module and a signal processor estimated at $50,000 per switch, and a $10,000 hardware module for each CCS connection at the switch to handle the multiplexing, data buffering, and hand shaking functions.

The cost for associated CCS increases quite dramatically as the number of switches in the network increases. This is illustrated graphically in Figure C-5. The point marked "analog switches" reflects the cost used for the 35 switch configuration of Alternative 1. The difference between this point and the curve at 35 switches represents the cost difference at the switch for implementing CCS. The cost for transmission does not vary for analog or digital switch CCS.

The cost for CCS in Alternatives 1, 5, and 6 (1,200 miles (1,931 km)) is quite high both in dollars and as a percentage of the total cost. The benefits derived from CCS affect quality of service. Although CCS can reduce the network offered load, it is generally not a cost reducing feature. The increase in quality of service corresponding to these cost expenditures has not been ascertained at this point in the development of the alternatives. Until the benefit of CCS can be determined quantitatively, it should be considered as an add-on option or feature.

TABLE C-XIII. DESIGN AND COST SUMMARY - SATELLITE APPROACHES

	Alternative 6		
	A[300 Miles (483 km)]	B[600 Miles (965 km)]	C[1200 Miles (1931 km)]
Terrestrial Facilities			
% Subscriber Traffic	47%	62%	81%
Switching			
Total Terminations	13,835	18,709	26,898
Number of Switches	68	52	63
Backbone			
Trunks	486	506	891
Channels	2,996	4,170	6,570
Ave IST length (Miles/km)	318/512	341/549	389/626
Access			
Access lines	7,843	10,369	13,758
Ave length (Miles/km)	45/72	64/103	58/93
Cost/Month (1000)	$4,153	$5,781	$8,334
Satellite Facilities			
% Subscriber Traffic	53%	38%	19%
Transponders	3	2	1
Earth Stations	42	30	17
Cost/Month (1000)	$3,499	$2,649	$1,452
Total Cost/Month (1000)	$7,652	$8,430	$9,786
Total Cost/Year (1000)	$91,824	$101,160	$117,432

TABLE D-XIV. 1985 COST OF APPROACHES UTILIZING SATELLITE
(Thousands of Dollars per Month)

	Alternative 6		
	A (300 Miles (483 km))	B (600 Miles 1965 km))	C (1200 Miles (1931 km))
Terrestrial Facilities	$4,153	$5,781	$8,334
Access	(1,245)	(2,045)	(2,447)
Switching	(870)	(1,105)	(1,420)
Backbone	(1,271)	(1,838)	(3,076)
CCS	(767)	(793)	(1,391)
Satellite Facilities	$3,499	$2,649	$1,452
Earth terminals	(882)	(540)	(255)
Space segment	(400)	(283)	(142)
Software/control	(333)	(173)	(83)
Earth Terminal Access	(1,884)	(1,653)	(972)
Monthly Total	$7,652	$8,430	$9,786

TABLE C-XV. ANALYSIS OF CCS COST

Alternative	Cost/Month (Thousands of Dollars)	CCS Cost (Thousands of Dollars)	CCS as Percent of Total Cost
1	$16,397	$2,504	15%
2	11,575	876	8%
3	14,199	190	1%
4	15,683	126	1%
5	11,204	3,008	27%
6 (A)	7,652	767	10%
6 (B)	8,430	793	9%
6 (C)	9,786	1,391	14%

For the alternatives identified where associated CCS costs are high, non-associated CCS should be considered. This should provide most of the desired features and at a lower cost. Cost differences can be determined when a non-associated CCS network is defined. However, any determination of the value of CCS will depend on a quantification of the benefits and cost derived both for associated and non-associated CCS.

5. COST OF MULTI-LEVEL PRECEDENCE AND PREEMPTION (MLPP)

The cost of MLPP is a cost incurred at the switch. In the present analog AUTOVON switch, MLPP is one quarter of the total cost of a termination. In digital switches, MLPP is likely to be implemented through software. Here, while cost depends on the total number of switches, for the range of switches considered in this study, it is half the total cost per termination. As shown in Table C-XVI, MLPP for the private-line switched implementations represents about the same fraction of the total system cost regardless of the number of switches or whether the switch is analog or digital. The primary reason for this is that in the analog switch alternatives, switch cost represents about 30% of the total cost whereas in the digital switch private-line alternatives, switching is about 15% of the total cost. Thus, in the former case MLPP cost represents a quarter of the total termination cost and in the latter, one half; thus, the overall impact is to preserve the relative MLPP cost.

In the alternatives implemented through the DDD, MLPP applies only to the operational traffic and is thus a small percentage of total cost. In the satellite alternative, MLPP costs are nearly constant for the three options, reflecting the fact that the total switching costs are increasing as space segments costs are decreasing. The switching costs are monotonically increasing even though the number of switches do not, because the total number of switch terminations, which is the basis for both switch and MLPP cost, is also monotonically increasing.

6. COST OF OPERATIONAL TRAFFIC

The operational traffic requires 4,530 access line] and has a busy hour traffic of 600 erlangs. A total of 534 locations is involved. Design A is based on locating the new digital switches at existing AUTOVON sites. Design A, shown in Table C-XVII,is used for Alternatives 3 and 4. Another option for the operational traffic is to leave the geographic locations of the switch unconstrained and develop a minimum cost design. This is shown as Design B, which contains 17 switches. Since placement is optimal, switch placement at the subscriber locations minimizes access line length, and reduces the total access cost by 30%, with almost no cost increase in the total switching and backbone cost. Because of the increase in switches, the cost of CCS is proportionately higher. The net result is a 16% cost reduction. Because of survivability considerations, the use of existing AUTOVON sites is included in the costs for Alternatives 3 and 4, that is, Design A.

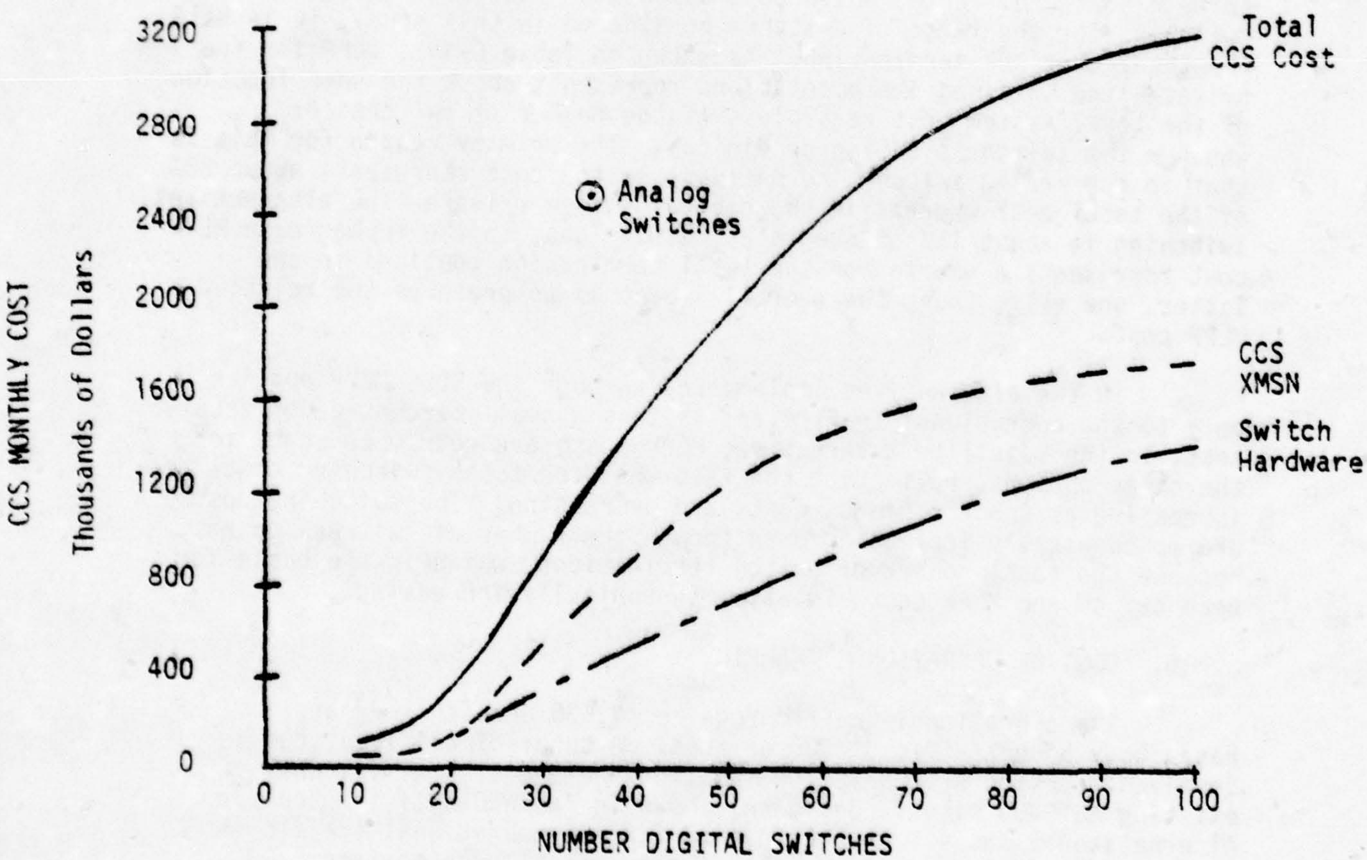

Figure C-5. Associated CCS Cost

TABLE C-XVI. ANALYSIS OF MLPP COSTS

Alternative	Cost/Month (Thousands of Dollars)	MLPP Cost (Thousands of Dollars)	MLPP As Percent of Total Cost
0	$14,015	$1,167	8%
1	$16,397	$1,143	7%
2	$11,575	773	7%
3	$13,973	$ 440	3%
4	$15,683	$ 155	1%
5	$11,204	$ 930	8%
6 (A)	$7,652	$ 435	6%
6 (B)	$8,430	$ 552	6%
6 (C)	$9,786	$ 710	7%

TABLE C-XVII. OPERATIONAL TRAFFIC DESIGN AND COST

COMPONENTS	DESIGN A	DESIGN B
Switches	10	17
Access Lines	4,539	4,539
Locations	534	534
COST ($1,000/Month)		
Access	$2,111	$1,428
Switching	310	338
Backbone	512	609
CCS	126	203
Total	$3,059	$2,578

VI. COST SENSITIVITIES

The preceding discussion on costing presented the assumptions used for the development of the cost estimates. With regard to the cost influencing assumptions, relative inflation rate, digital switch cost, transmission cost, and earth terminal cost are perhaps the most critical. Sensitivities based on the TELPAK tariff were not studied since it is believed that this offering will not be available by 1982.

1. INFLATION

While telecommunication costs to the subscriber are increasing at 9% annually, the analysis for the 1978-1985 period indicates that technological cost improvements as well as an improved inflationary outlook will combine to produce a net 5% annual escalation rate. The 9% rate is also a possibility. Table C-XVIII presents the monthly recurring cost for each alternative for both rates. By increasing the annual rate from 5% to 9%, 1985 costs increase an average of 30% for all alternatives, with Alternative 5 experiencing a 39% increase and Alternative 6 (A) a 25% increase. In terms of cost-ranking, Alternatives 2 and 5, and 0 and 3 switched order with each other.

2. SWITCH COST

A major cost issue of Alternatives 2 through 6 is the cost of a digital switch. Ranges of switch hardware cost are in the order of 30%. On top of this is the tariff to carrier cost ratio which can vary from 0% to 30%. The switch cost can therefore vary from $20/ termination to $80/termination. Cost sensitivities over the range $0-$100 are plotted in Figure C-6. For a switch charge below $30, Alternatives 3 and 0 switch ranking; otherwise over this large range, the relative cost order is unchanged. The major impact of switch cost is in Alternatives 2, 5, and 6 which experience a variation of about 30% in the range shown. Alternatives 3 and 4 follow with a 17% difference within the 0-100 range. Alternatives 0 and 1, not having digital switches, show no change on this graph.

The variation in switch cost produces at most a 15% change from the nominal $50 termination charge. Considering the wide range chosen, switch termination charges do not play a vital role in influencing the overall system cost, given a particular network design. Note, however, that the designs using a zero cost switch and a $100 cost switch could be significantly different in terms of the composition of terminations, access line mileages, and backbone channel mileages. Changes in switch cost can be compensated for by design changes, resulting in even lower cost differences. Compared with the relative uncertainty in the inflation rate, the uncertainty in switching cost remains at most a second or third order effect. Its main impact is in network design rather than in overall cost.

TABLE C-XVIII. COST SENSITIVITY TO INFLATION RATE
(Thousands of Dollars/Month)

Alternative	Rate of Inflation 5%	Rate of Inflation 9%	% Increase
0	$14,015	$18,220	30%
1	$16,397	$21,316	30%
2	$11,575	$15,110	31%
3	$13,973	$17,848	28%
4	$15,683	$20,336	30%
5	$11,204	$15,612	39%
6 (A)	$ 7,652	$ 9,604	26%
6 (B)	$ 8,430	$10,819	28%
6 (C)	$ 9,786	$12,849	31%

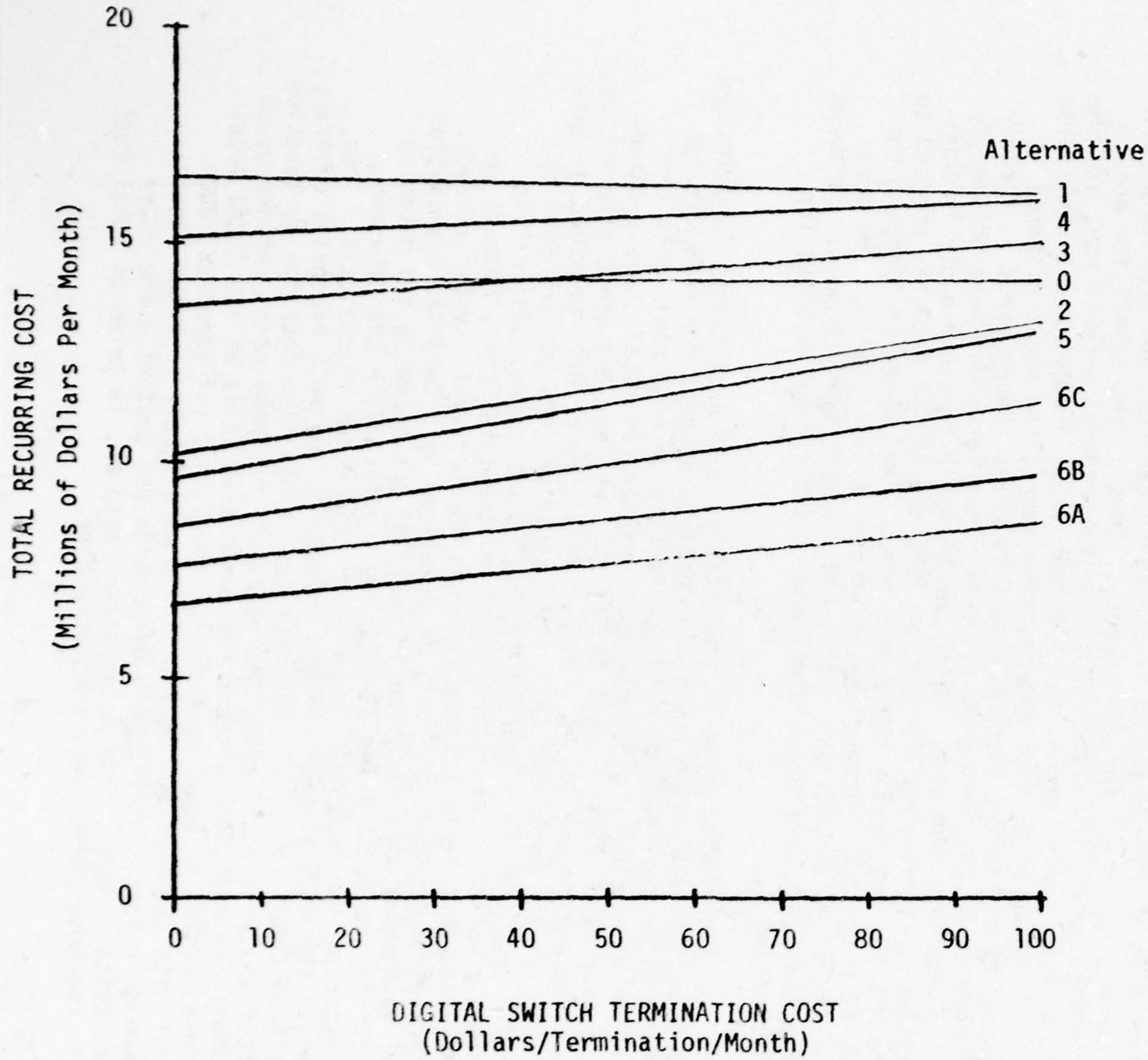

Figure C-6. Sensitivity to Digital Cost

The lack of available resources precludes a more thorough examination of the impact of switch cost to network design.

3. COST OF TRANSMISSION

While the uncertainty in the cost of transmission is perhaps not as large as that in switching, the impact of transmission cost on total cost is certainly more significant. Transmission cost consumes from 50% to 80% of the total cost, except for Alternative 4 which is almost entirely transmission. While many areas of uncertainty can be identified in the projected transmission tariffs, one area is particularly significant for two reasons. This is the tariff for access transmission. This tariff contains the greatest uncertainty, and the access area costs, except for Alternative 5, predominate transmission cost. Furthermore, over the past few years, the short distance transmission tariffs have been most voltile. Uncertainty is further introduced by the fact that all subscriber locations were assumed to be in MPL rate center B. While the MPL-BB rate could apply in some instances, it is possible that by 1985 the MPL-AA rate, as opposed to the MPL-BB, may typify the access area. The impact of applying the MPL-AA rate to the access area is shown in Table C-XIX. The cost ranking of Alternatives 1 and 4, and 2 and 5, were changed. In terms of actual cost decreases, a maximum of 11% change is noted for Alternative 2.

A different type of transmission cost uncertainty is exhibited in Alternative 4 which primarily consists of cost for WATS service. These costs are based on a GOS of P045 to be compatible with the design of the other alternatives. However, as noted, this provides the subscriber with a total GOS of P045 whereas the other alternatives have an end-to-end GOS of P13. If WATS service were provided to this criteria, the number of WATS lines could be reduced from 6879 to 3704, resulting in a cost of $9,286,000 per month. While this clearly makes a significant impact on the total cost, it must be realized that these costs were based on an overall system average. More accurate costs can only be developed by a detailed examination of each subscriber location in terms of its incoming and outgoing traffic and destination of outgoing traffic. Both the data and resources are lacking to accomplish this detailed analysis. Thus, while the WATS alternative was costed for the most expensive coverage, all of CONUS for a full business day, a detailed location by location cost analysis could alter the magnitude of these costs, either up or down. In addition, offsets for commercial calls at the local level were assumed to equal the cost of additional (if required) DDD circuits (non-private line). It is more likely that the benefit would in fact significantly overshadow the cost of these extra circuits. Hence, this alternative could be, in terms of total cost to the Government, very cost effective.

TABLE C-XIX. COST SENSITIVITY TO ACCESS AREA TRANSMISSION TARIFF
(Thousand of Dollars/Month)

Alternative	Access Area Tariff		
	MPL-AB	MPL-AA	% Decrease
0	$14,015	$12,753	9%
1	16,397	15,121	8%
2	11,575	10,334	11%
3	13,973	12,890	9%
4	15,638	15,308	2%
5	11,204	10,724	4%
6 (A)	7,652	7,002	8%
6 (B)	8,430	7,710	8%
6 (C)	9,786	9,091	7%

4. COST OF SATELLITE EARTH TERMINALS

Since the earth terminal for networks such as that of Alternative 6 have not yet been constructed or delivered, the production cost and resulting tariff estimate are uncertain at this time. As discussed in section 3, C the monthly cost of an earth terminal for Alternative 6 can range from $10,000 to $20,000 per month. Using these figures, the change in the total monthly recurring cost can be computed, keeping in mind that at 300 miles (483 km) the earth terminal cost is an additional $6,000 because two additional satellite transponders are required, and at 600 miles (965 km) the cost is an additional $3,000.

The results of the sensitivity analysis are shown in Table C-XX. Note that even though the total cost uncertainty in the earth terminal is 33%, the cost of earth terminals is at most 12% of the total recurring cost, or 25% of the space related network which includes the terrestrial tails to the earth terminals. The total uncertainty in the earth terminal cost, as a percent of total network cost, is 3%, 2%, and 1% respectively for options A, B, and C.

5. TOTAL COST UNCERTAINTY

The individual cost uncertainties previously discussed are now combined for all the alternatives to develop the total cost uncertainty. It is again pointed out that these uncertainties are for a specific network design. As the costs of the network components change, the network could be redesigned such that in all likelihood the overall impact is minimized. An analysis such as this requires a redesign for each possible change in cost. Lack of adequate resources precluded a study of this detail. In lieu of this, uncertainties based on fixed 1985 designs were costed. It is further pointed out that Alternatives 3, 4, and 6 are based upon services which do not yet exist. In Alternative 6, an estimate of the cost for the satellite service was made; however, in Alternative 3 and 4 substitute services were costed. The cost uncertainty analysis is based upon the uncertainties inherent in these substituted services, rather than in any uncertainty of the cost of the desired service vice that costed. This latter sensitivity could not be performed.

The uncertainties were divided into two major groups; up-side risk and down-side risk. The up-side risk includes all those issues which would tend to increase cost. These consist of inflation, hardware cost uncertainty, and hardware cost to tariff conversion uncertainty. The uncertainty in inflation rate applies to all alternatives. As previously noted, the nominal estimates were made using a 5% compound inflation rate, although a 9% rate is also possible. The up-side risk must consider the impact of this increased rate of inflation. The cost uncertainty of the new hardware items, switches, and earth terminals, as well as the uncertainty in converting the cost of these items to a

TABLE C-XX. COST SENSITIVITY TO EARTH TERMINAL COST

Alternative 6	Monthly Recurring Cost (1000)	Earth Terminal Cost as % Total Cost	Cost of Earth Terminal	
			$10,000/MO	$20,000/MO
A	$7,652	12%	$7,442	$7,862
B	$8,430	6%	$8,280	$8,580
C	$9,786	3%	$9,701	$9,871

tariff, also form part of the up-side risk. The hardware cost for a digital switch could increase by 10% and the cost for an earth terminal could rise from $15,000 to $20,000. As noted previously, the uncertainty in converting from a procurement cost to a tariff charge can be as high as 30%. This 30% factor applies to both switch and earth terminal costs.

The down-side risk consists of those uncertainties which tend to lower the nominal cost. This consists of lower than expected hardware cost and a lower access transmission rate. With regard to switching, the per termination charges could be halved for a number of reasons: (a) MLPP may not be required in an all digital switched network, especially with CCS; and (b) technology may improve more rapidly than projected. The lower expected cost for earth terminals ($10,000) was previously noted. With regard to Alternative 4, it was noted that the WATS charge has a large down-side potential. All these considerations are combined to produce the net cost of the down-side potential.

The costs for the up-side risk and the down-side risk are shown in Table C-XXI. When added and subtracted from the nominal estimate, the high and low estimates are developed. The same results are presented in Figure C-7 in bar chart form.

TABLE C-XXI. COST UNCERTAINTY
(Dollars in Thousands/Month)

Alternative	Up-side Risk	Down-side Risk	Monthly Recurring Cost		
			High	Nominal	Low
0	$4,205	$1,262	$18,220	$14,015	$12,753
1	5,434	1,276	21,831	16,397	15,121
2	4,248	1,963	15,823	11,575	9,612
3	4,021	1,464	17,994	13,973	12,509
4	4,798	6,837	20,481	15,683	8,801
5	5,519	1,410	16,723	11,204	9,794
6 (A)	3,051	1,295	10,713	7,652	6,357
6 (B)	3,249	1,423	11,679	8,430	7,007
6 (C)	3,940	1,490	13,726	9,786	8.296

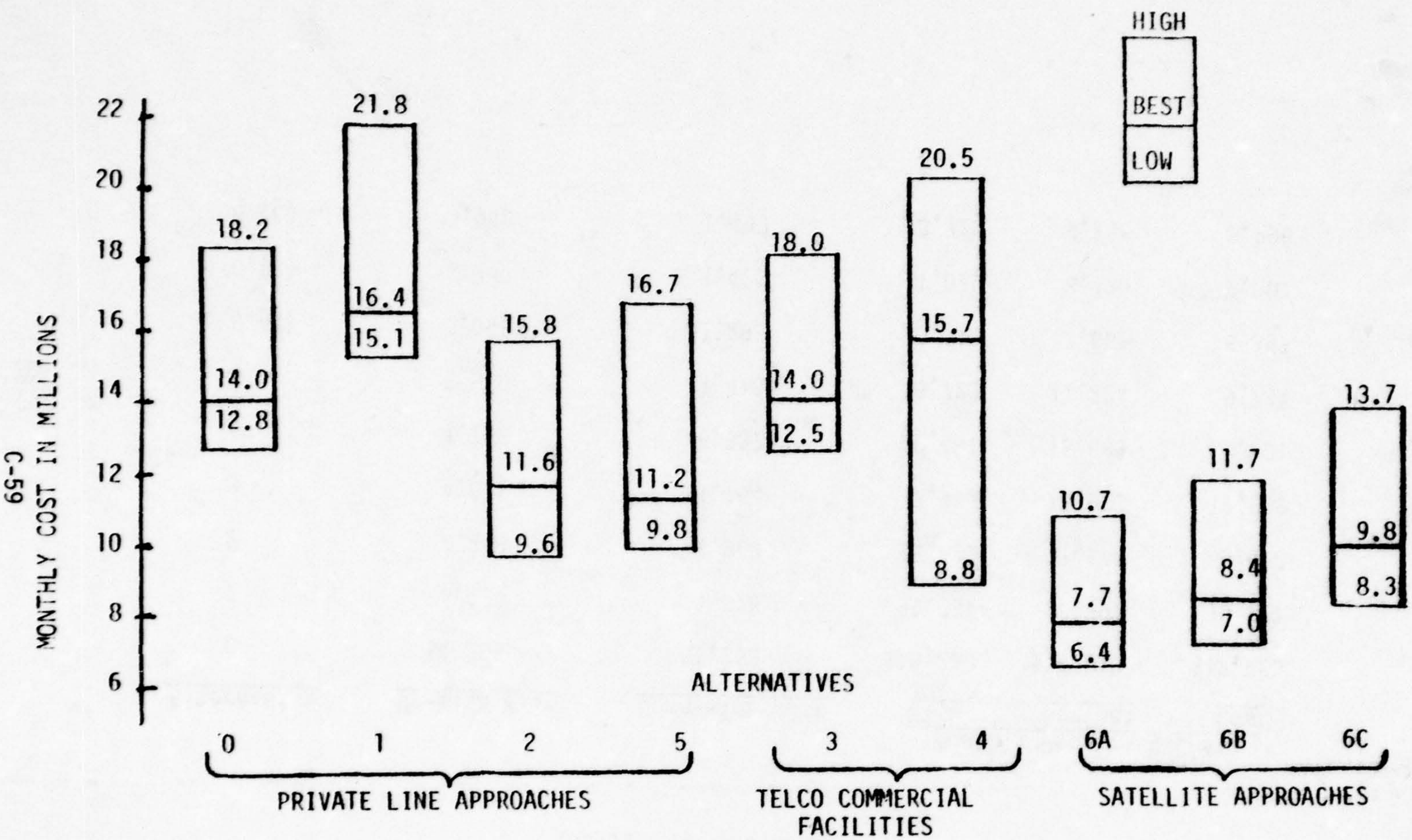

Figure C-7. Cost Comparison of Alternatives

VIII. FY 82/92 PERIOD ECONOMIC ANALYSIS

The six alternatives which were analyzed and costed represent specific options at different points in the 1982-1992 planning horizon. The cost comparisons, as previously noted, do not represent economic comparisons for the planning horizon. In order to develop an economic analysis over the 1982-1992 period it is necessary to define a set of implementations for each year concerned. To this end, a set of eight ten-year implementation strategies have been generated and defined in Table C-XXII. Table C-XXIII lists the underlying assumptions. These have taken the low cost features of each of the six AUTOVON alternatives and combined them into a small set of possible transition strategies.

Strategy A is simply Alternative 1 without CCS. This represents a baseline for the period, assuming that between 1978 and 1982 switches are eliminated to minimize the cost of the current CONUS AUTOVON Network. CCS was deleted since it has an extremely low benefit to cost ratio. Strategy A has a flat cost profile in the 1982-1992 time frame of $166,716,000 per year in terms of constant 1985 dollars. This is $118.5 millions in constant 1978 dollars and is about 18% higher than current CONUS AUTOVON costs under the existing tariffs.

Strategy B represents an implementation of Alternative 3 but without CCS. Administrative traffic is handled as in Alternative 3. Operational traffic during the 1982-1986 period is handled using ten existing AUTOVON switches. Because it was assumed that digital switches cannot be implemented prior to 1985 (see Table C-XXIII), an initial operational traffic capability using ten existing AUTOVON sites and switches is postulated, being phased out by 1987. Operational Design B, without CCS, is phased in during the 1985-1987 period. For cost reasons, CCS is not included in this alternative. The phasing of costs for Alternative B is shown in Table C-XXIV. A three-year period was used to phase in the operational Design B and phase out the AUTOVON operational facilities. For the analog facilities, costs were developed by substituting analog switch costs for Operational Design A and deleting CCS costs. All costs shown are in constant 1985 dollars, in thousands of dollars. Division by the factor 1.41 will result in constant 1978 dollars, under the assumed 5% average rate of escalation which considers net change caused by technological cost/performance reduction and inflation.

Strategy C represents an implementation of Alternative 4, i.e., the WATS alternative. Operational traffic is handled identically with that of Strategy B. Administrative traffic is carried over WATS during the 1982-1992 period. By 1987 it is expected that smart, digital PBX's will be prevalent among CONUS AUTOVON subscribers. Such PBX's can minimize administrative communications cost by selecting optimum routes over the DDD. It is assumed that such PBX's can result in a 20% decrease of the DDD charges. The phasing of costs for Strategy C is shown in Table C-XXV. The impact of smart PBX's begins in 1985 and continues to its maximum of 20% in 1987.

TABLE C-XXII. TEN YEAR TRANSITION STRATEGIES

Strategy	Definition
A	Alternative 1 throughout 1982-1992 but without CCS.
B	Alternative 3 for administrative traffic throughout 1982-1992. Analog operational, without CCS, in 1982-1986 period. Operational Design B, without CCS, in 1985-1992 period.
C	Administrative Traffic on WATS in 1982-1986 period. Administrative Traffic on WATS using smart PBXs in 1987-1992 period. Operational same as Alternative B.
D	Analog Switches of Alternative 1 during 1982-1988 period, without CCS. Digital Switches (3) at Alternative 1 sites during 1985-1992 period. New Digital Switches (26) of Alternative 2 during 1987-1992 period. Digital Switches have CCS provision.
D-1	Same as D except addition of CCS transmission during 1985-1992 period.
E	Analog Switches of Alternative 1 during 1982-1988 period, without CCS New Digital switches at old sites (4) during 1985-1992 period. Digital Switches of Alternative 5 (78) during 1987-1992 period.
F	Analog Switches as in Alternative E. New Digital Switches at old sites (4) as in Alternative E. Alternative 6 during 1987-1992 period. CCS included.
G	Analog switches of Alternative 1 during 1982-1986 period. SBS-like service during 1985-1992 period. Partial adminstrative traffic (26%) on WATS during 1985-1992 period. Operational Design B during 1985-1992 period. CCS included.

TABLE C-XXIII. TRANSITIONS ASSUMPTIONS

1982	WATS and No. 4 ESS backbone available
1985	Earliest possible implementation of digital switches at existing AUTOVON sites
	Beginning of SBS-like offering suitable for DCS usage
1987	Earliest possible implementation of digital switch at camp/post/station sites
	Subscriber locations have smart digital PBXs
1989	Complete implementation of new technology approaches possible

Strategy D represents an implementation of Alternative 2, transitioning from Alternative 1. During 1982-1984, this alternative is identical with Strategy A. Note that Alternatives 1 and 2 have three switch locations in common. Hence, in 1985, three AUTOVON switches are terminated and replaced with digital switches. During 1987-1989 the remaining 26 switches of Alternative 2 are phased in at subscriber locations, and the analog switches are phased out. This phasing is shown in Table C-XXVI. Since the local subscribers can be expected to have digital switching during this period, a cost sharing is assumed. This sharing could take the form of a larger switch than would normally be obtained for the local subscriber, with the Mildeps and DCA sharing the cost. Alternative 2, having the least number of switches (29), has the least cost for associated CCS. Thus, if associated CCS is to be implemented, Strategy D offers the most economical choice. Accordingly, Strategy D-1 is defined to be identical with Strategy D, except that it has CCS. Provisions for CCS were included in the digital switch costs for Strategy D. The phasing of costs for both Strategy D and Strategy D-1 is shown in Table C-XXVI. The CCS cost increment is for transmission only; the hardware and software costs are included in the cost of the digital switch. Thus, transition to CCS, because it requires only the addition of transmission, can take place any time during the 1985-1992 implementation of Strategy D.

Strategy E implements Alternative 5. Table C-XXVII presents the switch and cost phasing for this transition. Since there are four common switch locations between Alternatives 1 and 5, four new digital switches are installed in 1985, replacing the four analog switches of Alternative 1. The analog switches are completely phased out by 1989. As shown in Table C-XXVII, the digital switches of Alternative 5, the remaining 78, are phased in over the 1987-1989 period. These 78 switches also enjoy the benefit of cost sharing with the local subscriber. This is reflected in the phased costs.

Strategy F, illustrated in Table C-XXVIII, implements Alternative 6A. Since Alternative 6 employs the same sites as Alternative 5, the phasings of Alternative 1 during the 1982-1988 period and of the four digital switches are identical. The remaining 64 digital switches are phased in over the 1987-1989 period as are the space and space related network. Alternative 6 is fully implemented in 1989. Cost sharing is also applied to the 64 switches. The features of CCS could be employed in this transition strategy because by combining terrestrial and satellite facilities, strategy F is inherently more complex in terms of network management and system control. With regard to cost, CCS represents 10% of the total annual charges for Alternative 6A. Thus, CCS is included in this strategy and in the costs shown in Table C-XXVIII.

Strategy G uses an SBS-like service for 70% of the administrative traffic. The balance is over WATS. The distribution and phasing of

TABLE C-XXIV. STRATEGY B

	FY 82/92 Planning Horizon										
	82	83	84	85	86	87	88	89	90	91	92
Monthly Cost Phasing (1985 $/1000/ Month)											
Administrative Traffic	$11,076	$11,076	$11,076	$11,076	$11,076	$11,076	$11,076	$11,076	$11,076	$11,076	$11,07
Analog Operational	$ 3,510	$ 3,510	$ 3,510	$ 2,340	$ 1,170						
Operational Design B				$ 792	$ 1,584	$ 2,375	$ 2,375	$ 2,375	$ 2,375	$ 2,375	$ 2,37
Monthly Totals	$14,585	$14,586	$14,586	$14,208	$13,830	$13,451	$13,451	$13,451	$13,451	$13,451	$13,45
Total Annual Cost (1985 $1000)											
Annual Totals	$175,032	$175,032	$175,032	$170,496	$165,960	$161,412	$161,412	$161,412	$161,412	$161,412	$161,41

TABLE C-XXV. STRATEGY C

	FY 82/92 Planning Horizon										
	82	83	84	85	86	87	88	89	90	91	92
MONTHLY COST PHASING (1985 $/1000/Month)											
Administrative	12,624	12,624	12,624	11,783	10,942	10,100	10,100	10,100	10,100	10,100	10,100
Analog Operational	3,510	3,510	3,510	2,340	1,170						
Operational Design B				792	1,584	2,375	2,375	2,375	2,375	2,375	2,375
Monthly Totals	16,134	16,134	16,134	14,915	13,696	12,475	12,475	12,475	12,475	12,475	12,475
TOTAL ANNUAL COST (1985 $/1000)											
Annual - Totals	193,608	193,608	193,608	178,980	164,352	149,700	149,700	149,700	149,700	149,700	149,700

TABLE C-XXVI. STRATEGY D

	FY 82/92 Planning Horizon										
	82	83	84	85	86	87	88	89	90	91	92
SWITCH PHASING											
Analog Switches	35	35	35	32	32	22	12				
Dig. Switches at Von Sites				3	3	3	3	3	3	3	3
Dig. Switches at Remaining Alt 2 Sites						8	17	26	26	26	26
Monthly Cost Phasing (1985 $/1000/Monthly)											
Analog Facilities	13,893	13,893	13,893	13,512	13,512	8,733	4,763				
Dig. Switches at Von Sites				44	44						
Alt 2 Facilities (W/CCS)						4,177	7,596	11,013	11,013	11,013	11,013
Monthly Totals	13,893	13,893	13,893	13,556	13,556	12,910	12,359	11,013	11,013	11,013	11,013
CCS Cost Increment (XMSN only)				59	59	213	387	562	562	562	562
TOTAL ANNUAL COST (1985 $/1000)											
Strategy D	166,716	166,716	166,176	162,792	162,792	154,920	148,308	132,156	132,156	132,156	132,156
Strategy D-1	166,716	166,716	166,716	163,380	163,380	157,476	152,952	138,900	138,900	138,900	138,900

TABLE C-XXVII. STRATEGY E

	FY 82/92 Planning Horizon										
	82	83	84	85	86	87	88	89	90	91	92
SWITCH PHASING											
Analog Switches	35	35	35	31	31	21	11	0	0	0	0
Dig. Switches at Von Sites				4	4	4	4	4	4	4	4
Dig. Switches at Remaining Alt 5 Sites						25	50	78	78	78	78
Monthly Cost Phasing (1985 $/1000/Month)											
Analog Facilities	13,893	13,893	13,893	13,335	13,385	8,336	4,366				
Dig. Switches at Von Sites				51	51						
Alt 5 Facilities						2,615	4,830	7,312	7,312	7,312	7,312
Monthly Totals	13,893	13,893	13,893	13,436	13,436	10,951	9,196	7,312	7,312	7,312	7,312
TOTAL ANNUAL COST (1985 $/1000)											
Annual Totals	166,716	166,716	166,176	161,232	161,232	131,412	110,352	87,744	87,744	87,744	87,744

the traffic load and costs for this transition option are shown in Table C-XXIX. Cost for the SBS-like service is developed from Alternative 6. CONUS AUTOVON and WATS cost were distributed based on the traffic phasing shown in Table C-XXIX. The cost reducing benefit of smart PBX's on WATS cost and the cost sharing of digital switches by the local subscriber, both take place in 1987. Since WATS traffic is greatly reduced from that of Strategy C, the impact of the smart PBX's is assumed to start in 1987 at maximum WATS utilization rather than in 1985 as in Strategy C. Operational traffic uses Design B, which has 17 digital switches. Because of the mix of transmission media, CCS is employed and its costs are included.

An economic analysis was performed on the eight transition strategies for the 1982-1992 period. Using the 5% net rate of escalation and a 10% discount rate, the ten-year present worth of each strategy was computed. The results are shown in Table C-XXX. These results show that for strategies where the administrative traffic goes over the public telephone network, the total costs, including those for operational traffic, are the highest. Switched private-line designs and designs based upon an SBS-like service can be developed and implemented at about the same economic cost. If associated CCS is a desired goal for the terrestrial facilities, implementation of Alternative 2 as in Strategy D-1 is cost attractive.

Over the ten-year period, the most attractive strategies reduce the life-cycle cost by at most 18%. This represents the economic worth today of annual reductions (refer back to Tables C-XXIV to C-XXIX) in excess of 50% which occur, as in Strategy E, in the 1989-1992 period as compared with 1982.

The economic analysis shows that there are a number of options which can be employed in various combinations to achieve cost savings; namely, Alternatives 1, 2, 4, 5, and 6, in the implementation strategies suggested in Strategies D, E, F, and G. Many of the economic benefits are linked with external activities such as technological developments in switching and transmission equipments, and implementation of local base communications facilities. From this cursory examination of economic alternatives over the 1982-1992 planning horizon it is clear that if economic benefits of measurable significance are to be achieved, the economic and technological external factors must be clearly identified and factored into decision points, and implementation milestones and options.

TABLE C-XXVIII. STRATEGY F

	FY 82/92 Planning Horizon										
	82	83	84	85	86	87	88	89	90	91	92
SWITCH PHASING											
Analog Switches	35	35	35	31	31	21	11	0	0	0	0
Dig. Switches at Von Sites				4	4	4	4	4	4	4	4
Dig. Switches at Remaining Alt 6 Sites						21	42	64	64	64	64
Monthly Cost Phasing (1985 $/1000/Month)											
Analog Facilities	13,893	13,893	13,893	13,385	13,385	8,336	4,366	0	0	0	0
Dig. Switches at Von Sites				58	58						
Alt 6A						2,696	4,970	7,287	7,287	7,287	7,287
Monthly Totals	13,893	13,893	13,893	13,443	13,443	11,032	9,336	7,287	7,287	7,287	7,287
TOTAL ANNUAL COST (1985 $/1000)											
Annual Totals	166,716	166,716	166,176	161,316	161,316	132,384	112,032	87,444	87,444	87,444	87,444

TABLE C-XXIX. STRATEGY G

	FY 82/92 Planning Horizon										
	82	83	84	85	86	87	88	89	90	91	92
TRAFFIC LOAD PHASING (ERLANGS)											
Analog AUTOVON	5,300	5,300	5,300	3,600	1,900	0					
SBS-LIKE service				1,000	2,000	3,290	3,290	3,290	3,290	3,290	3,290
WATS				500	1,000	1,410	1,410	1,410	1,410	1,410	1,410
Operational B				200	400	600	600	600	600	600	600
Monthly Cost Phasing (1985 $/1000/Month)											
Analog AUTOVON	13,893	13,893	13,893	9,437	4,981	0					
SBS-LIKE service				1,077	2,154	3,543	3,543	3,543	3,543	3,543	3,543
WATS				1,474	2,949	3,326	3,326	3,326	3,326	3,326	3,326
Operational B				860	1,718	2,578	2,578	2,578	2,578	2,578	2,578
Monthly Totals	13,893	13,893	13,893	12,848	11,802	9,447	9,447	9,447	9,447	9,447	9,447
TOTAL ANNUAL COST (1985 $/1000)											
Annual Totals	166,716	166,716	166,176	154,176	141,624	113,364	113,364	113,364	113,364	113,364	113,364

TABLE C-XXX. ECONOMIC ANALYSIS OF TEN YEAR TRANSITION STRATEGIES

Generic Category	Transition Strategy	AUTOVON Alternatives Implemented	Ten-Year Life Cycle Cost (Millions of Dollars)
DO NOTHING	A	1, without CCS	$1,124
USE OF PUBLIC NETWORK	B	1,3, Design A with Von switches, Design B, without CCS	$1,130
	C	1,4, Design A with Von switches, Network B, without CCS	$1,144
SWITCHED PRIVATE LINE	D	1,2, without CCS XMSN	$1,041
	D-1	1,2, with CCS	$1,058
	E	1,5, without CCS	$ 924
SBS-LIKE SERVICE	F	1,5,6A, with CCS	$ 925
	G	1,4,6A, Design B, with CCS	$ 939

XIX. CONCLUSIONS

The major conclusions based on the economic analysis study are summarized in Table C-XXXI. A private line switched network provides, over the 1982-1992 planning horizon, the least cost implementation of CONUS AUTOVON. This network, furthermore, can be implemented cost effectively using a mix of public toll (DDD), terrestrial switched private line, and satellite facilities. In conducting the cost analysis it was observed that the present tariffs for digital services (DDS) were too costly to be employed with a digital switch in an all-digital network; thus analog transmission (MPL tariffs) were used. However, in terms of carrier cost, digital transmission and digital switching are less than the analog counterparts. This is the result of the savings in equipments such as channel banks, the higher reliability of digital equipments, and the lower manpower requirements. For a number of reasons, these savings may not be reflected in the tariffs charged DoD. By combining the concepts proposed and in some cases implemented at the base/post level into future DCS plans, it is possible to achieve further economies in future implementations of CONUS AUTOVON than those individually identified in the AUTOVON alternatives.

The costs for the three major design approaches for CONUS AUTOVON are shown in Table C-XXXII. Designs which continue the present approach are based on combinations of Alternatives 1 and 2 over the 1982-1992 planning horizon. The TELCO developments reflect implementations of Alternatives 1, 3, and 4 over the planning horizon. The advanced concepts reflect mixes of Alternatives 1, 4, 5, and 6 over the ten year period. The range of cost reflects the options in which the basic aproaches can be developed. All approaches begin with Alternative 1 and then evolve to one or more of the CONUS AUTOVON alternatives associated with the design approach. It is noted that the advanced concepts as well as continuation of the present approach are in fact switched, private line networks.

The costs shown in Table C-XXXII represent the economic costs of the design approaches over the ten year period. Each approach provides some potential for reducing annual AUTOVON charges of Strategy A, the extension of the current AUTOVON into the 1982-1992 period without CCS. The potential for cost reduction can be quantified by comparing the annual cost incurred when the design approach is fully implemented with the cost of no change to the current AUTOVON. This potential for reduction is summarized in Table C-XXXIII for the three basic design approaches. By replacing the existing analog switches with digital switches and taking advantage of BASCOP plans, a potential reduction of 17% of the extended current CONUS AUTOVON cost is possible. By taking advantage of TELCO developments as well as employing smart PBX's at the subscriber level, one can reduce cost by 11%. In this

TABLE C-XXXI. CONCLUSIONS

- Private line switched network alternatives still provide the least cost implementation of CONUS AUTOVON.
- The public network such as WATS can be combined with a private line switched terrestrial and satellite facilities in a cost effective implementation of CONUS AUTOVON.
- The present tariff offerings are not amenable to an all digital transmission and switching implementation of CONUS AUTOVON.
- Digital transmission and switching result in a least cost implementation of a switched voice network.
- Future developments at the subscriber level will have a significant impact on the cost and strategy of implementing CONUS AUTOVON.

TABLE C-XXXII. TEN YEAR LIFE CYCLE COSTS

Design Approach	Ten Year Life Cycle Cost (Millions of Dollars)	
	Low	High
Continue present approach	$1,041	$1,124
Follow TELCO developments	$1,130	$1,144
Advanced concepts	$924	$939

approach, however, there is an additional benefit to be derived in that each subscriber with a WATS service has "free" access to the commercial world. This should result in significant cost offsets; unfortunately they could not be quantified. The advanced concepts approach has a potential for reducing costs by 47%. Since all these reductions occur at different periods of time within the 1982-1992 period, the economic worth of these reductions at the beginning of the ten year period as presented in Table C-XXXII does not vary as drastically from one approach to another.

In order for the potential reductions to take place, certain changes in our present way of doing business must take place. Basic changes in current tariff arrangements must occur for all alternatives except 1 and 4. In order for approaches using TELCO developments to become attractive from a cost point of view, departures from the current tariff arrangements (including the WATS tariff) must occur. Such departures could include a government use only tariff or tariffs based on the use of classmarks in the Bell system. These would permit DoD to take advantage of the economies inherent in a public network, and at the same time satisfy its communications needs.

The implementation of advanced concept approaches assumes that certain types of tariff arrangements will be possible in the 1982-1992 time frame with respect to digital switches and satellite communications services. Whether or not the details of such arrangements can be worked out is speculative at this time and dependent on the future regulatory environment. However, DCA must assume some active role in identifying the desired tariff arrangements and pressing for their implementation.

Defense Department and DCA policies, such as JCS MOP's, are based on the technology of the current analog CONUS AUTOVON. This is also true of the current AUTOVON Interface Criteria and the present doctrine by which DCA exercises operational direction and management control. These policies require a reexamination in light of emerging digital telecommunications technology in order for cost-effective variations of Alternatives 3, 4, 5 and 6 to be feasible. If required changes to these policies cannot be effected, then it is fruitless to consider these alternatives. In such an event, no real alternatives can be pursued.

The approach to obtaining communications services in CONUS needs to be examined. The cost reducing benefits of digital technology will not necessarily be reflected in future tariff offerings, especially for terrestrial facilities. In order for the DoD to avail itself of these benefits, approaches other than through regulated carriers and existing tariffed services will have to be explored. For example, desired

TABLE C-XXXIII. POTENTIAL FOR COST REDUCTION

Design Approach	Cost Reduction Potential
Continue Present Approach	17%
Follow Telco Developments	11%
Advanced Concepts	47%

transmission services could be obtained through the competitive processes with the least cost bidder then filing a tariff for the necessary service. Digital switches and earth terminals for Alternatives 5 and 6 could be obtained competitively through third party leasing arrangements. The method of acquisition thus is as much a parameter as switch location or grade of service in designing CONUS AUTOVON.

APPENDIX D

SURVIVABILITY

TABLE OF CONTENTS

	Page
I. QUALITATIVE SURVIVABILITY ANALYSIS	D-1
1. APPROACH	D-1
2. FACTS BEARING ON DCS PLANNING IN CONUS FOR NUCLEAR WAR	D-1
3. AUTOVON II PRECEPTS	D-3
4. DISCUSSION	D-6
5. CONCLUSION	D-7
II. QUANTITATIVE SURVIVABILITY ANALYSIS OF PRIVATE LINE SWITCHED NETWORKS	D-9
BIBLIOGRAPHY	D-22

LIST OF ILLUSTRATIONS

Figure	Title	Page
D-1	THREATS TO COMMUNICATIONS	D-2
D-2	SURVIVABILITY CHARACTERISTIC OF ALTERNATIVE 1	D-14
D-3	SURVIVABILITY CHARACTERISTIC OF ALTERNATIVE 2	D-15
D-4	SURVIVABILITY CHARACTERISTIC OF ALTERNATIVE 3	D-16
D-5	SURVIVABILITY CHARACTERISTIC OF ALTERNATIVE 4	D-17
D-6	OPERATIONAL TRAFFIC CARRYING CAPABILITY OF ALTERNATIVE 1	D-18
D-7	OPERATIONAL TRAFFIC CARRYING CAPABILITY OF ALTERNATIVE 2	D-19
D-8	OPERATIONAL TRAFFIC CARRYING CAPABILITY OF ALTERNATIVE 5	D-20
D-9	OPERATIONAL TRAFFIC CARRYING CAPABILITY OF ALTERNATIVE 6	D-21

LIST OF TABLES

Table	Title	Page
D-I	COLLATERAL DAMAGE (NUCLEAR) THREAT IMPACTS ON CONUS AUTOVON II ALTERNATIVES	D-4
D-II	DIRECT THREAT IMPACTS ON CONUS AUTOVON II ALTERNATIVES	D-5
D-III	THREAT IMPACT SUMMARY ON CONUS AUTOVON II ALTERNATIVES	D-8

I. QUALITATIVE SURVIVABILITY ANALYSIS

1. APPROACH. Survivability implies hostility and hostility implies an enemy. Survivability considerations can expand out of control unless care is taken to select factors which can make evaluations converge. A way to do this is to approach survivability from an enemy viewpoint. The enemy should be assumed intelligent, constrained by the level of hostility he is willing to risk, and limited to finite resources. If he is assumed to have infinite resources there can be no defense. For evaluating various command/control and communications (C^3) configurations some previous studies have considered that a modest percentage of the enemy's resources would be applied against C^3. Current estimates indicate a Soviet inventory of 4,000 strategic warheads and bombs.* AUTOVON II configurations necessitating enemy expenditures in the order of 100 nuclear assets would constitute a significant portion of those allotted against C^3.

An enemy would approach the objective of disrupting or exploiting CONUS communications with a diagram or a mental picture similar to figure D-1. Figure D-1 is a tree diagram of all threats to communications. The enemy would discount those threats which he could not control, e.g., natural disasters or would not use, e.g., conventional war. Three threat conditions which he could exploit against CONUS DCS are: (1) general nuclear war (collateral and direct nuclear effects); (2) military actions short of open conflict (sabotage and electronic warfare); (3) cold war (intercept).

2. FACTS BEARING ON DCS PLANNING IN CONUS FOR NUCLEAR WAR. The greatest stress to the DCS will come in a general nuclear war. The following are germaine to the DCS for both collateral nuclear effects and direct nuclear attack.

- CONUS DCS will rely heavily on common carrier grid (AT&T, WU, GTE, MCI, SBS, etc.).

- Commmunications do not have to be more survivable than the users.

- DCS communications facilities (owned or leased) are not designed to withstand direct nuclear blast attack.

- Collateral blast damage avoidance is practical and is practiced by major common carriers.

The use of the common carrier grid in CONUS is a constraint and also an asset. This grid for reasons of its own is very redundant. Exploitation of this redundancy is a way to mitigate losses from direct nuclear attack. War games have been played against this grid. A massive nuclear attack will cause significant reductions to it. However, past studies show that a substantial contiguous grid remains! This is the grid that the AUTOVON II should exploit.

*United States Military Posture for FY 1979 by Chairman of JCS, General George S. Brown, USAF, 20 Jan 1978. Document is unclassified.

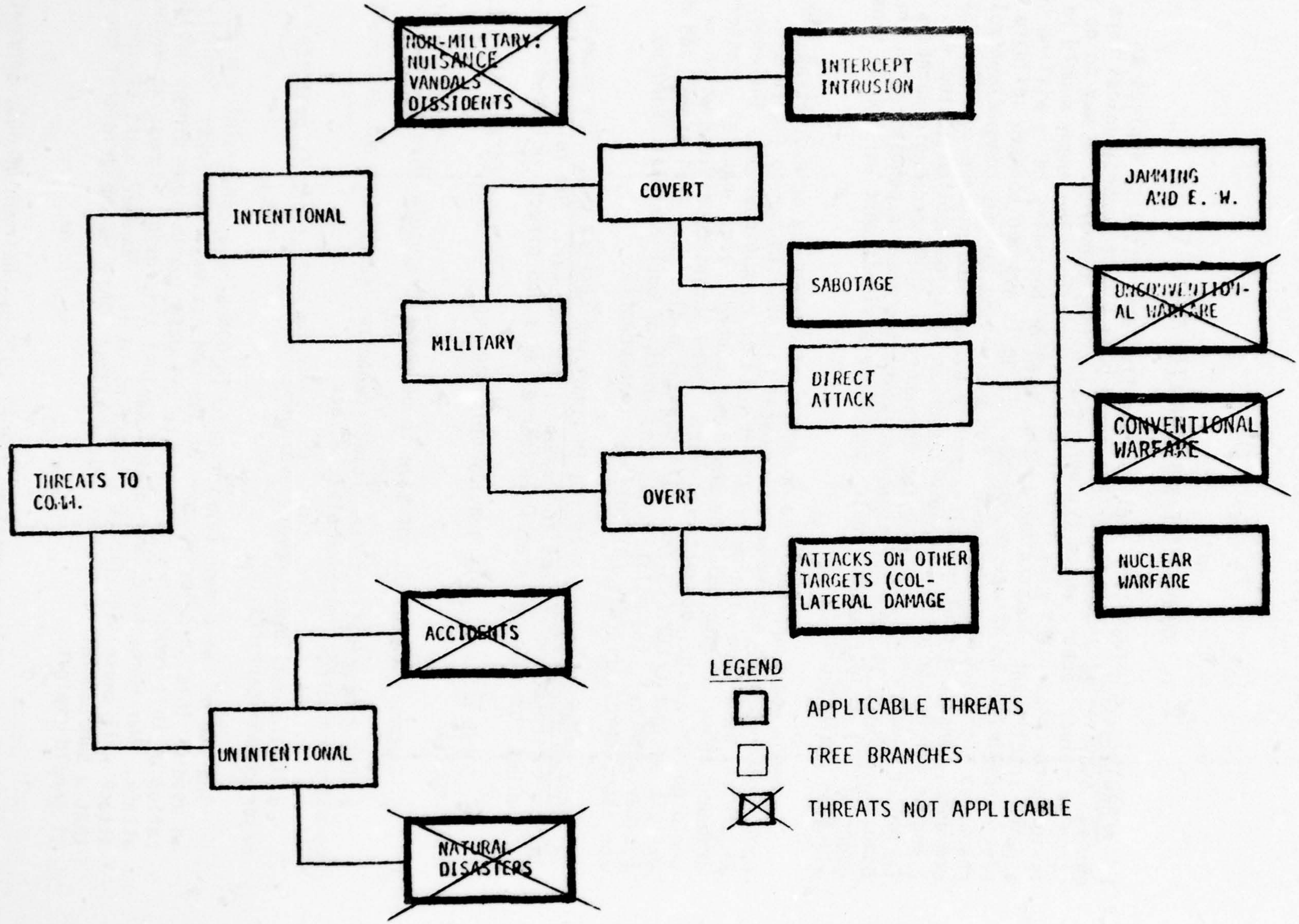

Figure D-1. Threats to Communications

3. AUTOVON II PRECEPTS. AUTOVON has a role to play in all situations from peace to general nuclear war. AUTOVON is:

- A workhorse in peacetime.

- A support to WWMCCS for all military situations from limited military engagements to general nuclear war.

- MEECN support in the transattack period.

- A possible source of communications in the reconstitution period.

Evaluation of CONUS AUTOVON II will consider first the general nuclear war situation.

The common carrier grids have been made less vulnerable to collateral damage by avoidance siting and modest (e.g., 50 PSI) hardening. AUTOVON II planning should not vitiate this asset. AUTOVON II switches should be sited outside of target areas to avoid collateral damage where switches serve users in different target areas. AUTOVON II must not be a bonus to an enemy intent on destroying other things.

All the AUTOVON alternatives will use the common carrier grids (terrestrial and satellite). No alternative can be more robust than the grid into which it is embedded. A cut set analysis of the many hundreds of nodes in the composite common carrier grids would establish a robustness upper bound for all alternatives against direct nuclear attack. The cut set analysis would have to "discount" losses to the grid from collateral effects and would have to treat the needs of the operational users from their operational locations.

The CONUS AUTOVON II configuration must also display substantial robustness against attacks which might be mounted in situations other than general nuclear war. Plausible EW or sabotage attacks against transmission routes or switch elements must not be capable of rendering CONUS AUTOVON II impotent.

The threat impacts of collateral damage, for each of the six CONUS AUTOVON II alternatives, are presented in Table D-I. Direct nuclear attack and direct attacks from sabotage, and jamming for the six CONUS AUTOVON II alternatives are presented in Table D-II. The cold war "direct attack threat" of intercept is also tabulated on Table D-II.

TABLE D-I. COLLATERAL DAMAGE (NUCLEAR) THREAT IMPACTS ON CONUS AUTOVON II ALTERNATIVES

CONUS AUTOVON II ALTERNATES (1)(2) / THREATS	CONTINUE PRESENT APPROACH		FOLLOW TELCO DEVELOPMENTS		NEW ADVANCED CONCEPTS	
	-1- MINIMUM ESSENTIAL CHANGES	-2- NEW DIGITAL SWITCHES DEDICATED TRUNKS	-3- NEW DIGITAL SWITCHES HOMED ON NO. 4 ESS (3)	-4- "VIRTUAL AUTOVON" ON DDD - (WATS) (3)	-5- MANY SMALL SWITCHES - SHORT AC-CESS LINES	-6- SATELLITE OPTION (3)
BLAST/GROUND SHOCK (4)	(5) (6)	(5) (6)	(5)(7)(8)	(5)(7)(8)	(6) (9)	(8) (9)
THERMAL EFFECTS	(10)	(10)	(10)	(10)	(10)	(10)
RADIATION EFFECTS	(11)	(11)	(11)	(11)	(11)	(11)
EMP	(12)	(12)	(12)(13)	(12)(13)	(12)	(12)
FALLOUT	(14)	(14)	(14)	(14)	(14)	(14)

NOTES:

(1) All AUTOVON II alternatives use varying portions of the common carrier grid. Recovery in peacetime from losses of individual facilities will be rapid and will cause minimal impact. Recovery in the transattack period will be sporadic and scenario dependent. Recovery in the post-attack period is also scenario dependent. No alternative appears to have a significant advantage over the others for recovery in hostile conditions.

(2) The CCS planned for all alternatives will be associative; i.e., it will transit, whenever possible, the same routes as trunks served.

(3) These alternatives incorporate an operational network which provides enhanced capability to select DoD subscribers. This network should be sized to assure FLASH non-blocking for operational subscribers.

(4) Nuclear blast and ground shock are the dominant damaging nuclear weapon effects against communications facilities operating on the ground.

(5) All but three of current AUTOVON switches have been located to avoid collateral blast damage. The three locations serve operational users within the same target area. They need not survive the destruction of the operational users. Those AUTOVON II alternatives using current locations other than the three will avoid collateral blast damage.

(6) Routing of trunk groups on current system has been at convenience of carrier. Some number of trunk groups are routed through target areas. The routing philosophy for traffic handling must be able to exploit trunks which are not lost due to collateral damage.

(7) The trunking via No. 4 ESS (some 140 locations) will be vulnerable to the extent that the No. 4 ESS's are in collateral damage areas. Further, the No. 4 ESS's will be controlled by a CCS network with 20 signal transfer point (STP) computers. The loss of these computers will render the No. 4 ESS's impotent. Evaluation of the 20 STP locations for collateral damage will also be needed for these alternatives.

(8) The trunks for operational network designed as a supplemental capability for operational users must be routed over common carrier transmission systems which avoid collateral damage. Tariffs exist for this type routing.

(9) The "balance concept" applies here. Switches serving users in one target area need not survive users in this area. Switches serving users in more than one target area should be located to avoid collateral blast damage.

(10) Thermal radiation can blind personnel and ignite flammable material outside or inside buildings (through windows). AUTOVON switches should be located in fireproof windowless buildings.

(11) The range of radiation from nuclear weapons in the atmosphere is short. The range for blast from strategic type weapons is dominant in the atmosphere. Radiation is a recognized threat to satellites. The more the utilization of satellites the greater the loss of network capability from this weapon effect.

(12) The EMP from a surface weapon is similar to lightning. For strategic type weapons its damaging range is less than for blast. Hardened facilities (e.g., 50 PSI) should be shielded against this weapon effect. The EMP from an exoatmospheric detonation (i.e., HEMP) is a ubiquitous phenomena within line-of-sight of detonation. This fast rise, high peak, short duration pulse has low energy. Possibility of disruption and some damage exist. By 1985 HEMP protection requirements will be established. Specifications for switches must include HEMP protection. HEMP impact on common carrier grids have been evaluated by SAFEGUARD, AT&T and others. Test results indicate damage unlikely and disruptions of long duration a low probability.

(13) The replacement of twistor type memories by insulated gate field effect transistor memories may render the public network more vulnerable to HEMP.

(14) Fallout is primarily a threat against operating personnel. Fallout is dependent upon yield height of burst, and winds. A protection factor of 100 for fallout should be included for any manned location.

TABLE D-II. DIRECT THREAT IMPACTS ON CONUS AUTOVON II ALTERNATIVES

CONUS AUTOVON II ALTERNATES / THREATS	CONTINUE PRESENT APPROACH		FOLLOW TELCO DEVELOPMENTS		NEW ADVANCED CONCEPTS	
	-1- MINIMUM ESSENTIAL CHANGES	-2- NEW DIGITAL SWITCHES DEDICATED TRUNKS	-3- NEW DIGITAL SWITCHES HOMED ON NO. 4 ESS (1)	-4- "VIRTUAL AUTOVON" ON DDD - (WATS) (1)	-5- MANY SMALL SWITCHES - SHORT ACCESS LINES	-6- SATELLITE OPTION (1)
BLAST/GROUND SHOCK (2)	(3)	(3)	(4)	(5)	(6)	(6)(7)
SABOTAGE	(8)	(8)	(8)	(8)	(8)	(8)
EW - JAMMING/ SPOOFING	(9)	(9)	(9)	(9)	(9)	(9)
EW - INTERCEPT	(10)	(10)	(10)	(10)	(10)	(10)

NOTES:

(1) These alternatives incorporate an operational network which provides enhanced capability to select DoD subscribers. This network should be sized to assure FLASH non-blocking for operational subscribers.

(2) No existing communications facility is hard enough to withstand blast from a direct nuclear attack. Redundancy of switches, trunks, and access lines with special traffic routing doctrines to exploit residual capabilities are used to mitigate losses from direct attack. All alternatives will exploit the common carrier long line grids. Cut set analyses of the collateral damage free portions of the common carrier grids would provide "bounding limits" to the AUTOVON alternatives. Robustness of alternatives should be measured against these limits.

(3) The polygrid traffic routing doctrine and related topology for current AUTOVON provide a substantial capability to reduce impacts of direct attack. An adaptive routing concept exploiting telemetry capabilities of planned CCS links could provide additional capabilities to circumvent direct attack losses. No topology or routing doctrine can be more robust than the "bounding limits" established for the common carrier grids.

(4) Connection of AUTOVON switches to No. 4 ESSs would result in a hierarchial topology. A refined attack could select the set of 20 STP's or any subset not destroyed by collateral damage. This would make the No. 4 ESS's inoperative. A cut set analysis of the No. 4 ESS configuration plus the operational network will be needed to determine robustness of this alternative.

(5) An indiscriminate direct attack on the switches of the DDD network without considering the attrition from collateral damage or the differences in communities served would be costly and likely ineffective. A more refined attack effort would consider that collateral damage could remove a number of the switches. Only a portion of those remaining serving operational users need be attacked. A cut set analysis of the DDD configuration plus the operational network will be needed to determine robustness of this alternative.

(6) An indiscriminate attack on the numerous switches could be costly and ineffective. A more refined attack would consider losses from collateral damage and would attack only the minimum number of on-base switches or common carrier nodes to disrupt this network. Cut set analysis needed.

(7) The network used to supplement the use of a satellite transmission capability must be redundant enough so that a direct attack on the satellite and the destruction of a few terrestrial nodes will not make this alternative less robust than other alternatives.

(8) The topology of all alternatives will require in a less than nuclear war condition simultaneous cutting by saboteurs of the common carrier grid at a large number of points to completely disrupt the network. Since sabotage teams are not 100% effective (estimates range from 30% to 80% success for a single attack), a large number of teams would be required. This would be difficult to do in CONUS and still maintain the surprise conditions necessary for success. Cut set analyses of the various topologies with attack costs for sabotage actions will be needed to establish the number of cuts for disruption. Isolation of various commanders is a more easily achievable sabotage action. Sabotaging the one or two access facilities into a command location could be effective in some situations. Added precautions for access facilities must be considered. The concern is greatest for Alternatives 1, 2, 3, and 4. For Alternatives 5, 6, access lines will be much shorter and frequently entirely on a protected base, camp or station; however, trunks from the on-base switches to other switches would transit base access facilities and could be vulnerable to sabotage.

(9) The jamming or spoofing threat to any alternative is unlikely against the LOS services provided by the common carriers. The enemy could jam or spoof AUTOVON circuits on, or "seize" the commercial domestic satellites.

(10) The Soviets have extensive intercept capabilities. Monitoring of AUTOVON trunks is possible in many locations when routed via LOS links. An important element in an intercept effort against switched networks is identification of number called. Implementation of CCS can make identification of the number called difficult or unavailable.

4. DISCUSSION. An examination of the information of Tables D-I and D-II shows that certain factors are common to all six alternatives. While they must be considered in implementing and/or costing each alternative, they do not constitute a factor which would distinguish one option from another in survivability situations. These are as follows:

- The common carrier terrestrial grid will be used for CONUS AUTOVON II transmission. The robustness of the portions not lost to collateral blast effects needs to be determined. A cut set analysis of the remaining contiguous common carrier grid, using a measure of effectiveness of Commanders connected to subordinates, is needed to establish a bound for all AUTOVON II alternatives.

- All alternatives will use CCS. The advantages for intercept denial are applicable to all; i.e., an enemy would have difficulty or be denied the number called when CCS is used.

- The collateral nuclear effects of thermal radiation and fallout will require that the structures housing the AUTOVON II switches be fireproof, windowless, and have adequate thickness of walls, etc., to assure a protection factor of 100 in the areas where there are operating personnel. Ancillary fallout protection for two weeks of buttoned-up operation would also be needed for all alternatives.

- Sabotage against the backbone portion of AUTOVON II is not a severe threat. Sabotage of access facilities to military locations may be a threat. In Alternatives 1, 2, 3, and 4, these access facilities will be "conduits" for access circuits to the AUTOVON switches. In Alternatives 5 and 6, many access lines will be on base and protected. However, the trunks from the AUTOVON switches located on base will then transit the access facilities from the base to the common carrier network. These will be vulnerable to sabotage. The conclusion is that sabotage of access facilities is a threat to all alternatives. Precautions against sabotage of access facilities to operational user locations must be taken for all alternatives. The SBS capability of Alternative 6 may not have off-base access facilities. It would be more robust than the others.

Three of the alternatives (3, 4, 6) are to be augmented with operational networks for operational users. These operational networks may compensate for the survivability weaknesses if adequately sized and may make these alternatives as robust as the others.

The following threats have different impacts on each alternative:

- The commercial satellites are vulnerable to jamming, spoofing, seizure and from nuclear radiation. Alternative 6 will use satellite transmission for administrative traffic over longer distances (e.g., 300 mi). Other alternatives will use commercial satellite as a supplement to the terrestrial networks.

• The enemy's ability to intercept commmunications is possible for all alternatives. However, the ability to intercept communications transmitted via satellite will be easier. The use of privacy equipment can make intercept of satellite transmission somewhat more difficult.

• Assuming that the guidance given in Table D-I is used in dealing with collateral blast damage avoidance, Alternatives 1, 2, and the supplemental subnets of 3 and 4, can be robust against collateral damage. The balance criterion (see glossary) applies to Alternatives 5 and 6. The switches will be located with their users and would be as survivable as their users. Portions of the networks of Alternatives 3 and 4 will be located in target areas. These portions of the networks for Alternatives 3 and 4 may be more vulnerable to collateral blast damage than the other alternatives.

• The direct nuclear blast attack threat must be measured against the robustness of the common carrier grid. No alternative can be more robust than the collateral damage-free portion of the common carrier grid. Current CONUS AUTOVON was tailored to exploit the collateral damage-free common carrier grid of the 1960's. There have been augmentations to the grid and also an increase in enemy weapons. Exact status requires cut set analysis. Preliminary assessment indicates that the number of current AUTOVON switches is comparable to the estimated number of common carrier nodes which must be eliminated to render AUTOVON communication impotent. The 20 STP's are less than this number. The portions of the network of Alternatives 3 and 4 will use the 20 STP's and are less robust than 1 and 2. The augmentation of Alternatives 3 and 4 by the operational networks may make these alternatives comparable. The large number of switches of Alternative 5 would be more robust. The vulnerability to direct nuclear attack on satellites makes Alternative 6 less robust than others.

5. CONCLUSION. A summary of the assessments of the robustness of the six alternatives to the threats is assembled in Table D-III. Configurations and site locations will require additional scrutiny to assure preferred positioning to avoid collateral damage and to exploit the collateral damage-free portions of the redundant common carrier grid. This scrutiny may bring changes in these assessments. A selection of the more robust portions of each alternative can result in a composite CONUS AUTOVON II configuration more resistant to all the plausible threats cited.

TABLE D-III. THREAT IMPACT SUMMARY ON CONUS AUTOVON II ALTERNATIVES

CONUS AUTOVON II Alts. / THREATS		CONTINUE PRESENT APPROACH		FOLLOW TELCO DEVELOPMENTS		NEW ADVANCED CONCEPTS	
		-1- MINIMUM ESSENTIAL CHANGES	-2- NEW DIGITAL SWITCHES - DEDICATED TRUNKS	-3- NEW DIGITAL SWITCHES - HOMED ON #4 ESS	-4- "VIRTUAL AUTOVON" ON DDD - (WATS)	-5- MANY SMALL SWITCHES - SHORT ACCESS LINES	-6- SATELLITE OPTION
COLLATERAL DAMAGE (NUCLEAR)	BLAST AND GROUND SHOCK	G	G	F	F	G	G
	THERMAL EFFECTS	G	G	G	G	G	G
	RADIATION EFFECTS	G	G	G	G	G	F
	ELECTRO-MAGNETIC EFFECTS (EMP)	F	F	F	F	F	F
	FALLOUT	G	G	G	G	G	G
DIRECT ATTACK	NUCLEAR BLAST AND GROUND SHOCK	F	F	M	M	F	F
	SABOTAGE	F	F	F	F	F	G
	ELECTRONIC WARFARE - JAMMING/ SPOOFING	G	G	G	G	G	F
	ELECTRONIC WARFARE - INTERCEPT	F	F	G	G	G	F

ROBUSTNESS: G = GOOD
F = FAIR
M = MARGINAL
P = POOR

II. QUANTITATIVE SURVIVABILITY ANALYSIS OF PRIVATE LINE SWITCHED NETWORKS

The objective of this section is to present quantitative measurements of traffic carrying capability of the subject alternatives, under several damage scenarios. The thesis of this section is that the survivability of an alternative is directly related to how that alternative's traffic carrying capability changes as the damage level (specifically switch outages) varies.

The presentation of the results herein follows an unusual format. Consequently the text will be devoted to an explanation of how to read the accompanying figures. The reader may then draw his own conclusions from the quantitative results.

The underlying premise of the analysis is that system level tradeoffs are necessary. That is, designing a survivable system involves selecting, out of many possible design options, a single design which meets a decision maker's criteria for system performance under both benign and hostile conditions (as well as other, e.g., economic, criteria). A major point to consider arises from the realization that an intelligent enemy will base an attack against communications on his knowledge of the design of the system. Thus, from an enemy's point of view, every different design option calls for a different attack. It is not possible to know in advance how, or whether, the communications system will be attacked. Therefore, we can only determine how different design options will perform after some given damage scenario occurs.

In this context, the different design options are chosen from the following list:

i) How much money is to be spent on the overall system. This is reflected in a monthly budget for each alternative.

ii) The technology and structural (e.g., collocation of subscribers and switches or not) options for the overall system. These issues are discussed, for each alternative, in other sections of this report.

iii) How many backbone switches are to be used in each alternative. It should be noted at this point that, while other sections of this report cite a specific number of backbone switches for each alternative, this appendix includes this number and also allows a wide excursion about the number. This excursion produces a tradeoff relation between the traffic carrying capability in damaged and undamaged modes of operation at fixed cost for each alternative.

The damage scenario possibilities are handled by damaging the network, for each alternative, through destruction of a specified number of backbone switches. This appendix considers the following damage scenarios:

i) Zero backbone switches destroyed. This allows the measurement

of traffic carrying capability of each alternative in an undamaged mode.

ii) 10, 20, and 30 backbone switches destroyed. This allows the measurement of traffic carrying capability of each alternative over a range of damage levels.

The results of the analysis have nothing to say about how the backbone switches were destroyed. A particular backbone switch may have been destroyed (rendered inoperable) by a satchel charge, a missile, HEMP, jamming, etc.. Whatever the cause, only the effect of rendering the backbone switch inoperable is considered by the analysis.

The approach used is to consider a large number of the possible design options and display the response of each to a set of the postulated damage scenarios. That is, for each evaluation one set of choices from the design options list is made; this set is then analyzed for its response to destruction of 0, 10, 20, and 30 switches. A preferable outcome and the alternative which is most likely to produce it can be chosen within the limits of uncertainty as to precisely how a real enemy would respond.

The outcomes of all analyses are shown in Figures D-2 through D-9. The figures should be considered in two groups:

i) Figures D-2 through D-5 show the outcomes with respect to total system traffic: administrative and operational, intra- and inter-switch, both in damaged and undamaged modes.

ii) Figures D-6 through D-9 show the outcomes for persons principally interested in the operational traffic carrying capability of each alternative in the damaged modes. This is measured by the traffic carrying capability of the damaged backbone network.

The remainder of this section will show how to read the accompanying figures by interpreting several of the design options and damage scenario possibilities and their associated outcomes.

Figures D-2 through D-5 refer, respectively, to Alternatives 1, 2, 5, and 6. All four figures follow the same format. The horizontal axis refers to the traffic carrying capability of the undamaged network. The vertical axis refers to the traffic carrying capability of the damaged network. Four curves are shown in each figure. The line at 45 degrees represents traffic carrying capacities in an undamaged (0 switch removed) network. The top curve refers to the damage scenario which removes 10 backbone switches; the middle curve removes 20; and the bottom curve removes 30. Each curve is produced by varying the design option of how many backbone switches to use in the network design; this choice may range from a minimum of 24 to a maximum of 384. A tick mark, with a number of parantheses beside it, is placed on each set of curves to indicate the actual number of backbone switches being proposed for each alternative. It should be noted that all curves within any one figure are constant cost curves; i.e., when the system design is changed, the total system cost does not change - rather, the total budget is re-allocated.

Consider the point labeled "96" on the top curve in Figure D-2. This point corresponds to an analysis where the design choices were:

i) Spend a total of $13.9 M/mo.

ii) Alternative 1 technology and structural options.

iii) Use 96 switches in the backbone.

The damage scenario destroyed 10 switches out of the total 96. The outcome of the analysis is:

i) Traffic carrying capability of the undamaged system is 5400 erlangs.

ii) Traffic carrying capability of the damaged system (10 switches destroyed) is 4450 erlangs.

The point on the middle curve of Figure D-2, immediately beneath the point labeled "96" on the top curve, corresponds to the same design choices as above; however the damage scenario in this case destroys 20 switches. The outcome of this analysis is:

i) Traffic carrying capabiity of the undamaged system is as above, 5400 erlangs.

ii) Traffic carrying capability of the damaged system (20 switches destroyed) is 3450 erlangs.

The point on the bottom curve of Figure D-2, immediately beneath the point labeled "96" on the top curve, corresponds to the same design choices as above; however the damage scenario in this case destroys 30 switches. The outcome of this analysis is:

i) Traffic carrying capability of the undamaged system is as above, 5400 erlangs.

ii) Traffic carrying capability of the damaged system (30 switches destroyed) is 2700 erlangs.

As can be seen, the tradeoff between undamaged and damaged system traffic carrying capability can be varied by varying the choice of the number of backbone switches in the design. That is, one can obtain better survivability, (as measured by throughput in a damaged situation) in return for poorer performance under routine conditions, without an increase in total system cost. For example, the choice can be made for 54 switches instead of 96. In this case one gives up approximately 300 erlangs of throughput in a damage environment in exchange for 500 erlangs improvement in a benign environment; there is no cost penalty one way or the other. Whether or not this is a good tradeoff is a matter for the decision making process.

Figures D-6 through D-9 refer, respectively, to Alternatives 1, 2, 5 and 6. All four figures follow the same format. The horizontal axis refers to the number of backbone switches (prior to damage) in the network. The vertical axis refers to the operational traffic carrying capability of the damaged backbone network. A horizontal dotted line on each figure denotes the operational traffic requirement. The tick mark with an asterisk above it on the horizontal axis of each figure denotes the number of backbone switches being proposed for each alternative. Three curves are shown in each figure. The top curve refers to the damage scenario which removes 10 backbone switches. The middle curve removes 20 and the bottom curve removes 30.

Each curve is produced by varying the design option of how many backbone switches to use in the network design; this choice may range from a minimum of 24 to a maximum of 384. It should be noted that all curves within any one figure are constant cost curves.

Each point on a curve corresponds to an analysis where the design choice is indicated on the horizontal axis, the damage scenario is indicated by which curve, and the outcome is read on the vertical axis. Thus, for example, the leftmost point on the top curve of Figure D-6 refers to an analysis where the design choice was to put 24 backbone switches in the design, the damage scenario destroyed 10 of these, and the outcome is a damaged system operational traffic carrying capability of 450 erlangs; below the requirement.

The above discussion should allow the reader to interpret the results of this Appendix. Drawing a conclusion from the results is a different matter. In the context of the tradeoffs presented there is no clear cut system choice which is superior to all others in every respect. Rather one can only indicate a preference based on individual subjective criteria as to the relative importance of damaged and undamaged system traffic carrying capability; what the actual communications needs and budgets of the DoD are; and finally the probability that we will ever have to use the network in a crisis.

One conclusion is possible if the cost of each alternative is not a consideration. That is, when all alternatives have the same number of switches, regardless of what that number is, Alternative 5 gives better traffic carrying capability, in both damaged and undamaged modes, than any other alternative.

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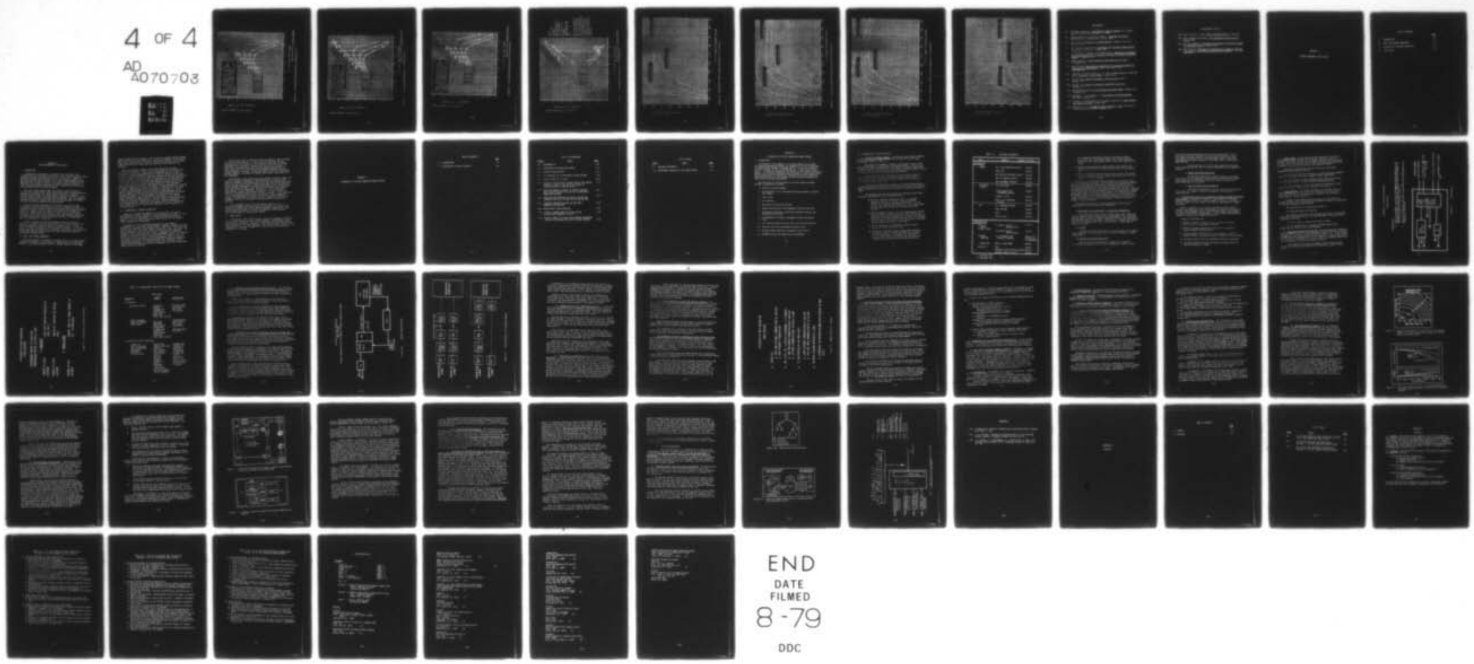

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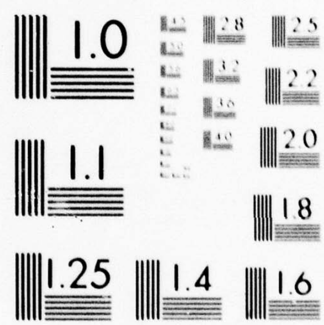

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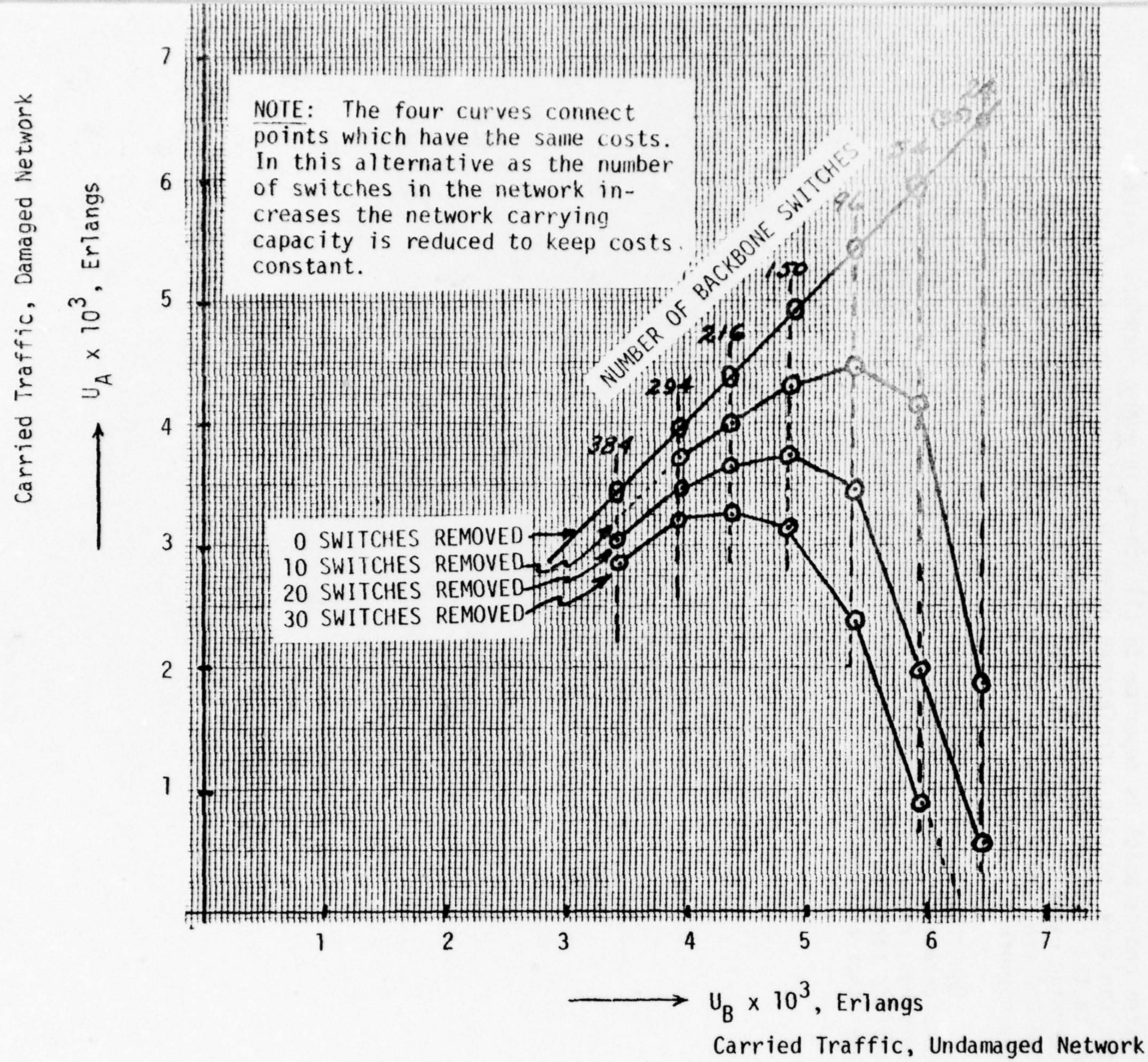


Figure D-2. Survivability Characteristic of Alternative 1

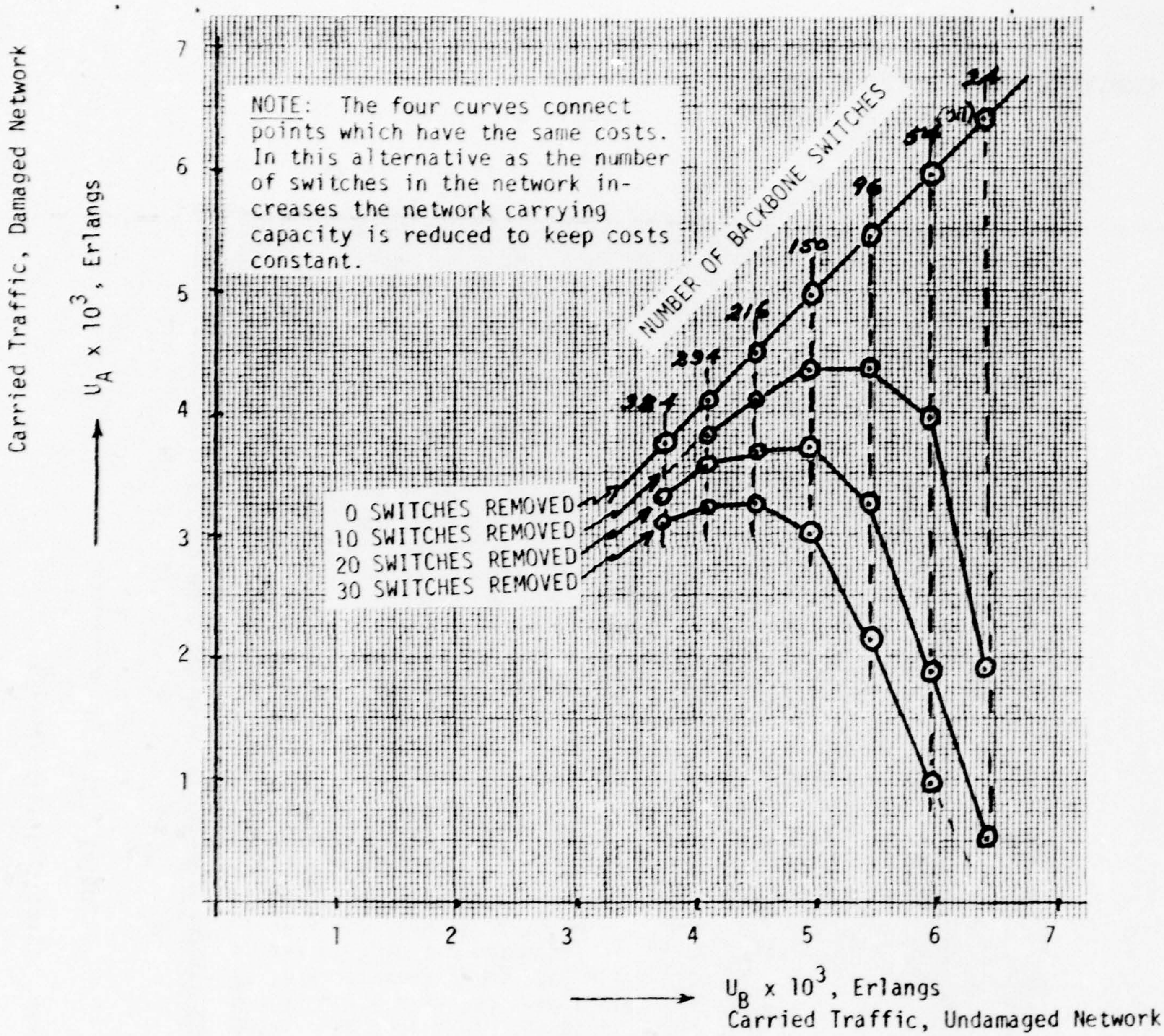


Figure D-3. Survivability Characteristic of Alternative 2

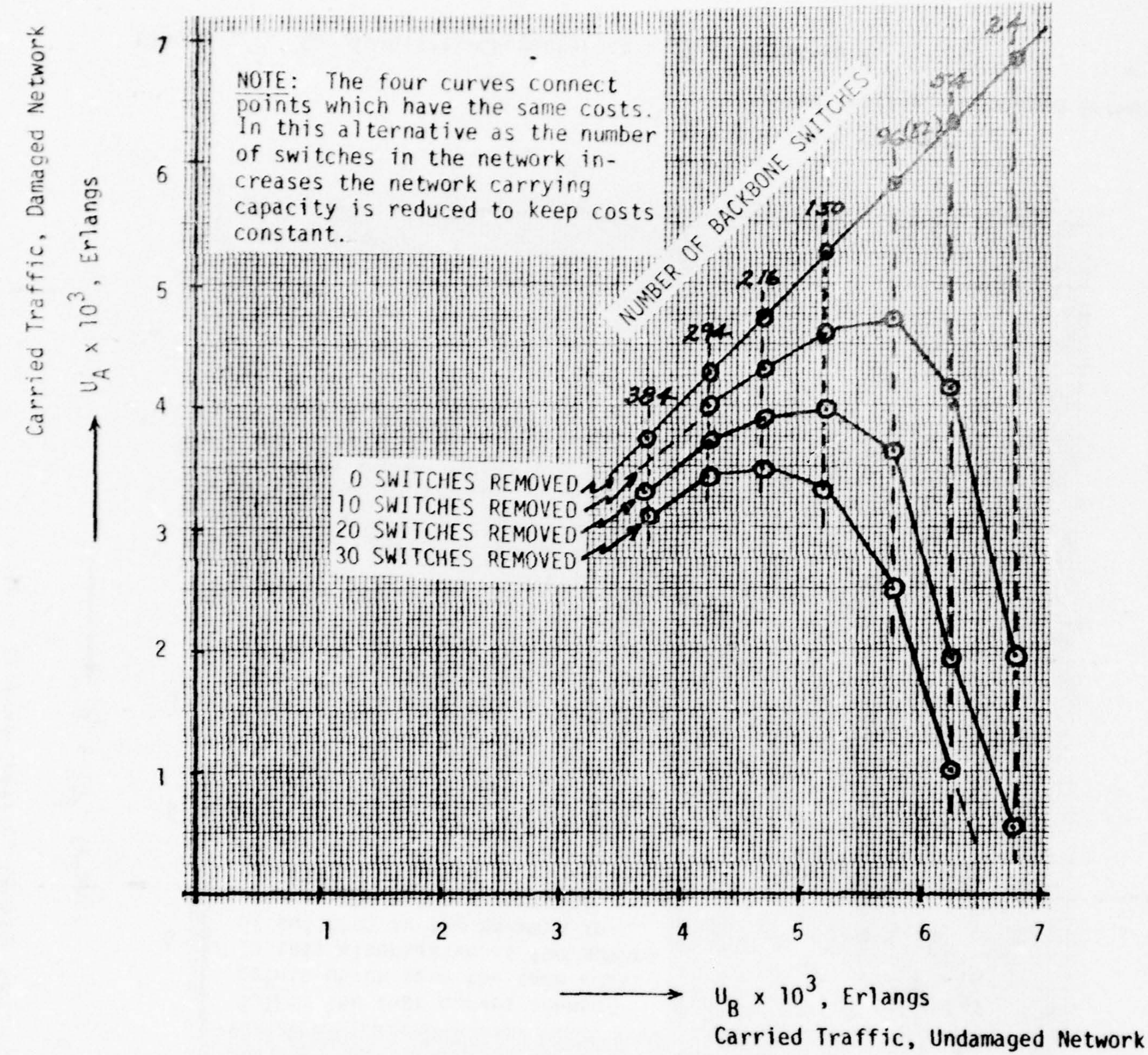
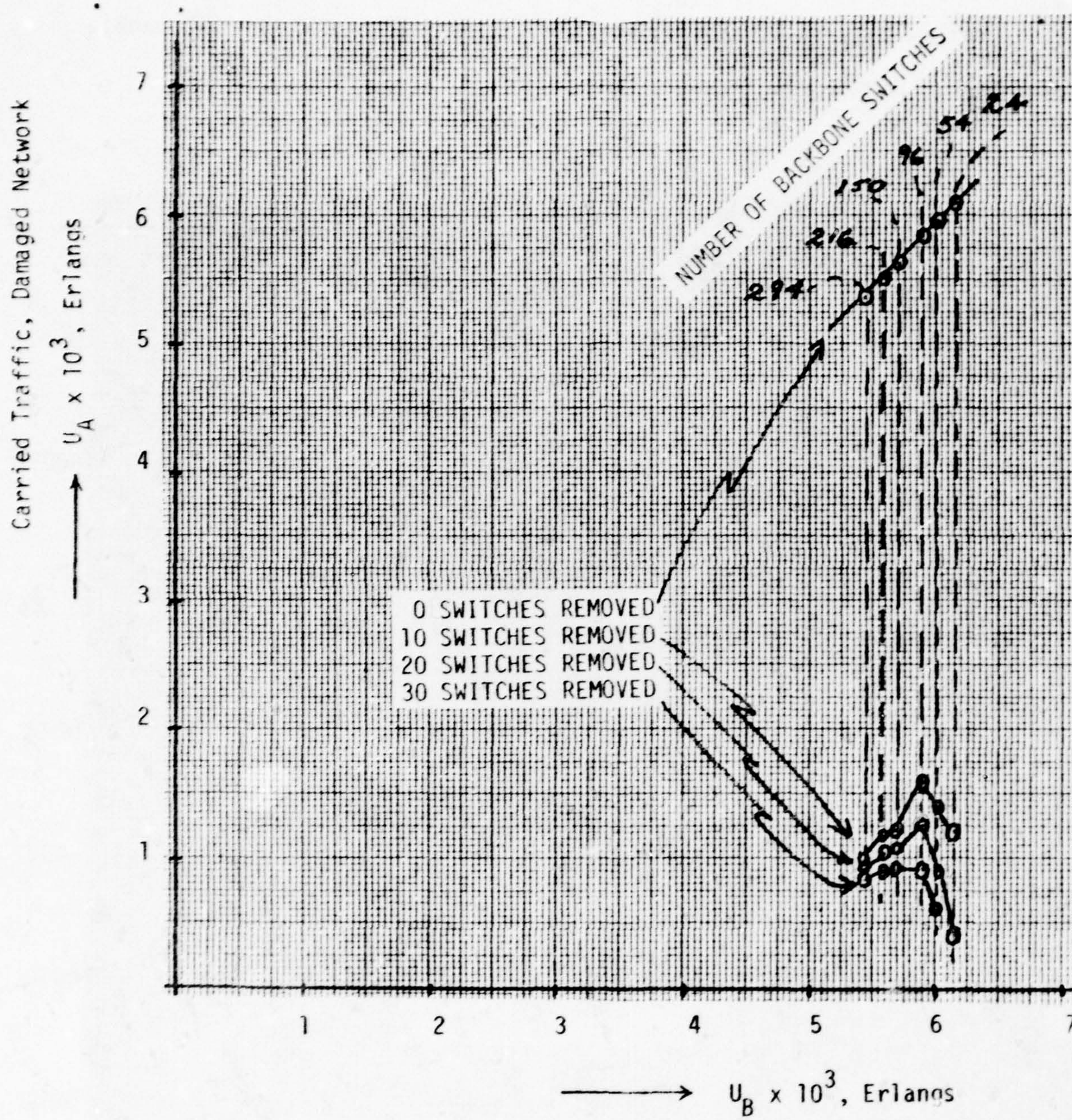


Figure D-4. Survivability Characteristic of Alternative 5



Notes

1. This figure assumes destruction of the satellite for U_A measurement. If satellite is assumed survivable, add 3000 Erlangs to U_A.

2. The four curves connect points which have the same costs. In this alternative a the number of switche in the network increases the network carrying capacity is reduced to keep cost constant.

Figure D-5. Survivability Characteristic of Alternative 6

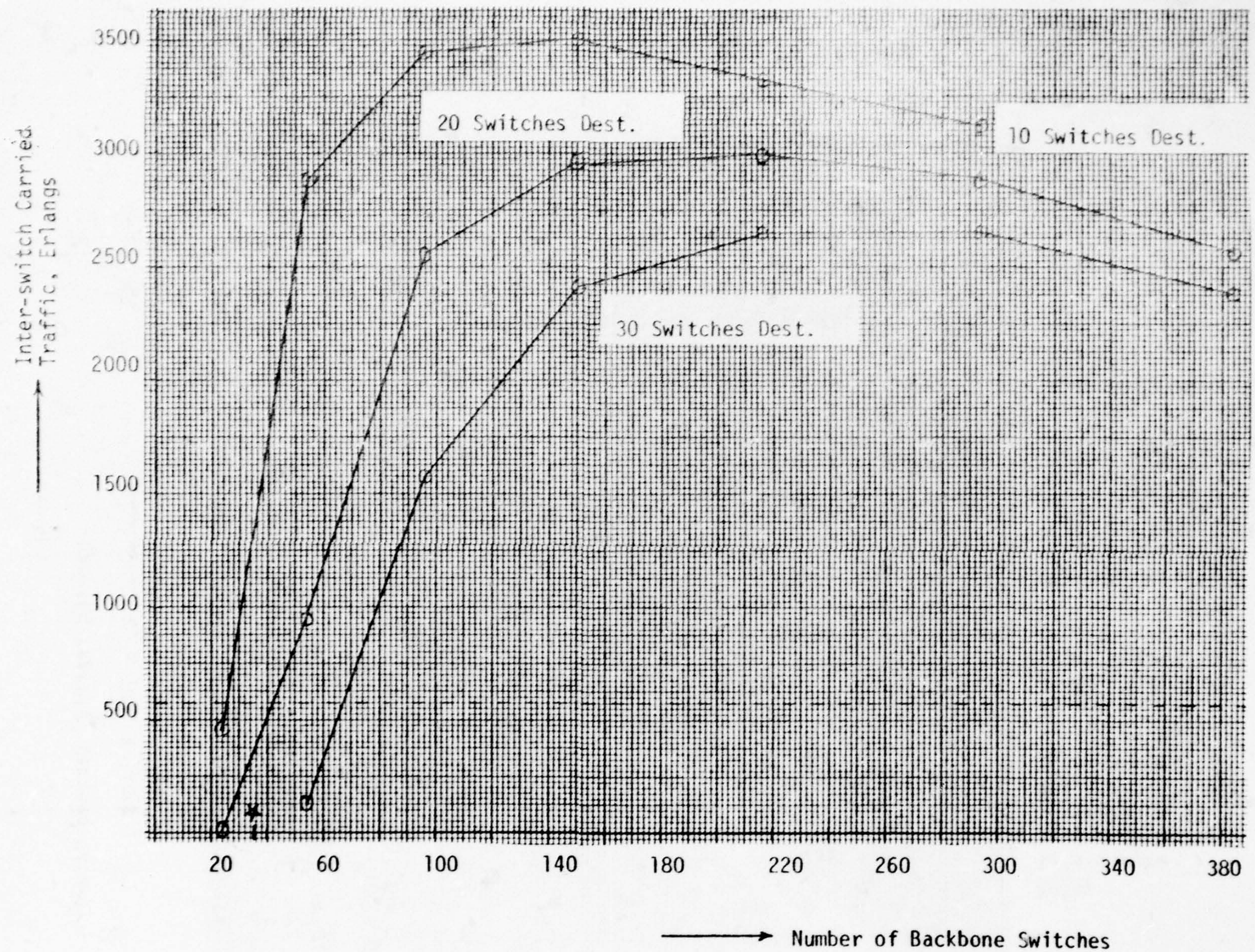


Figure D-6. Operational Traffic Carrying Capability of Alternative 1.

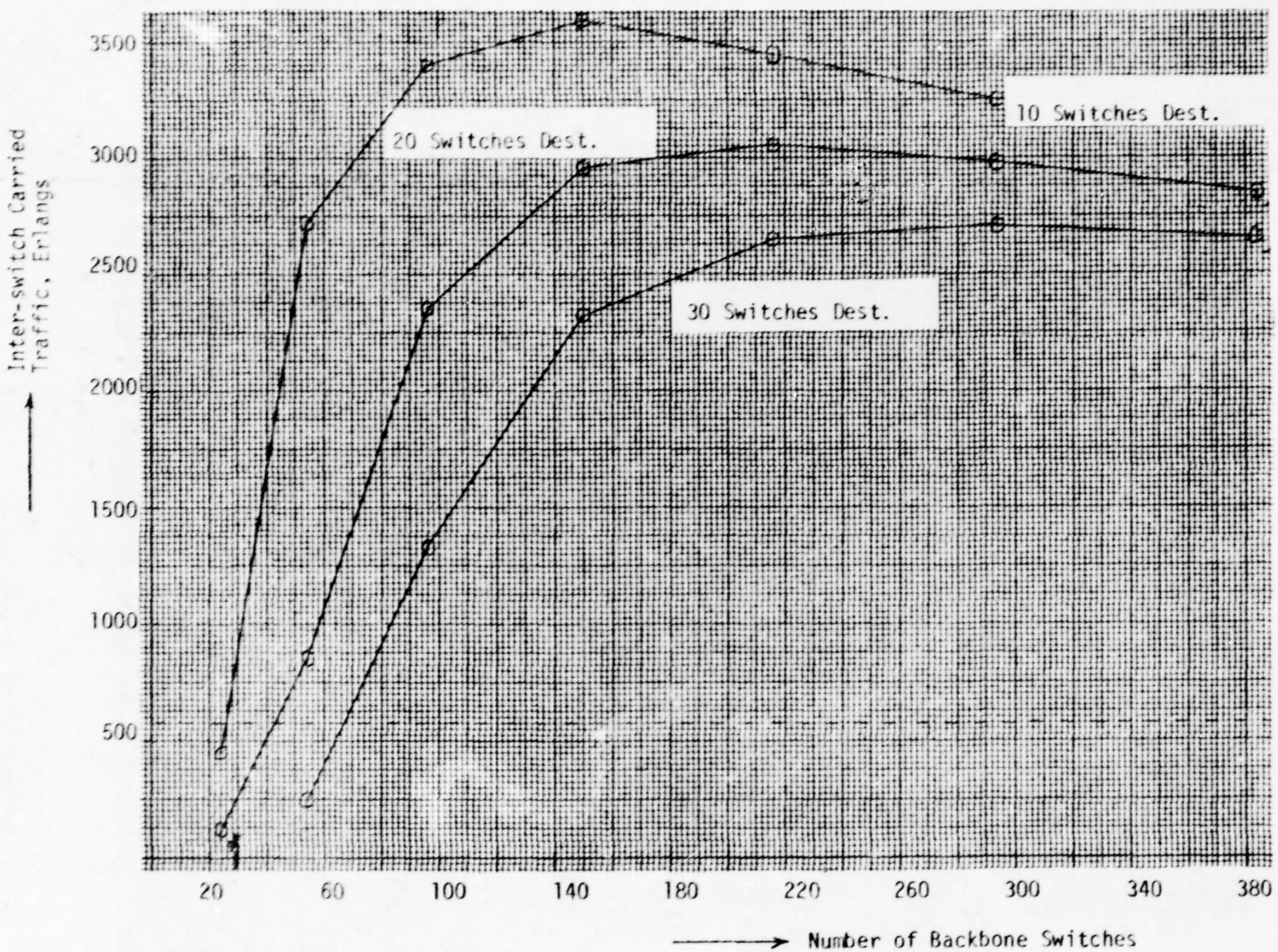


Figure D-7. Operational Traffic Carrying Capability of Alternative 2

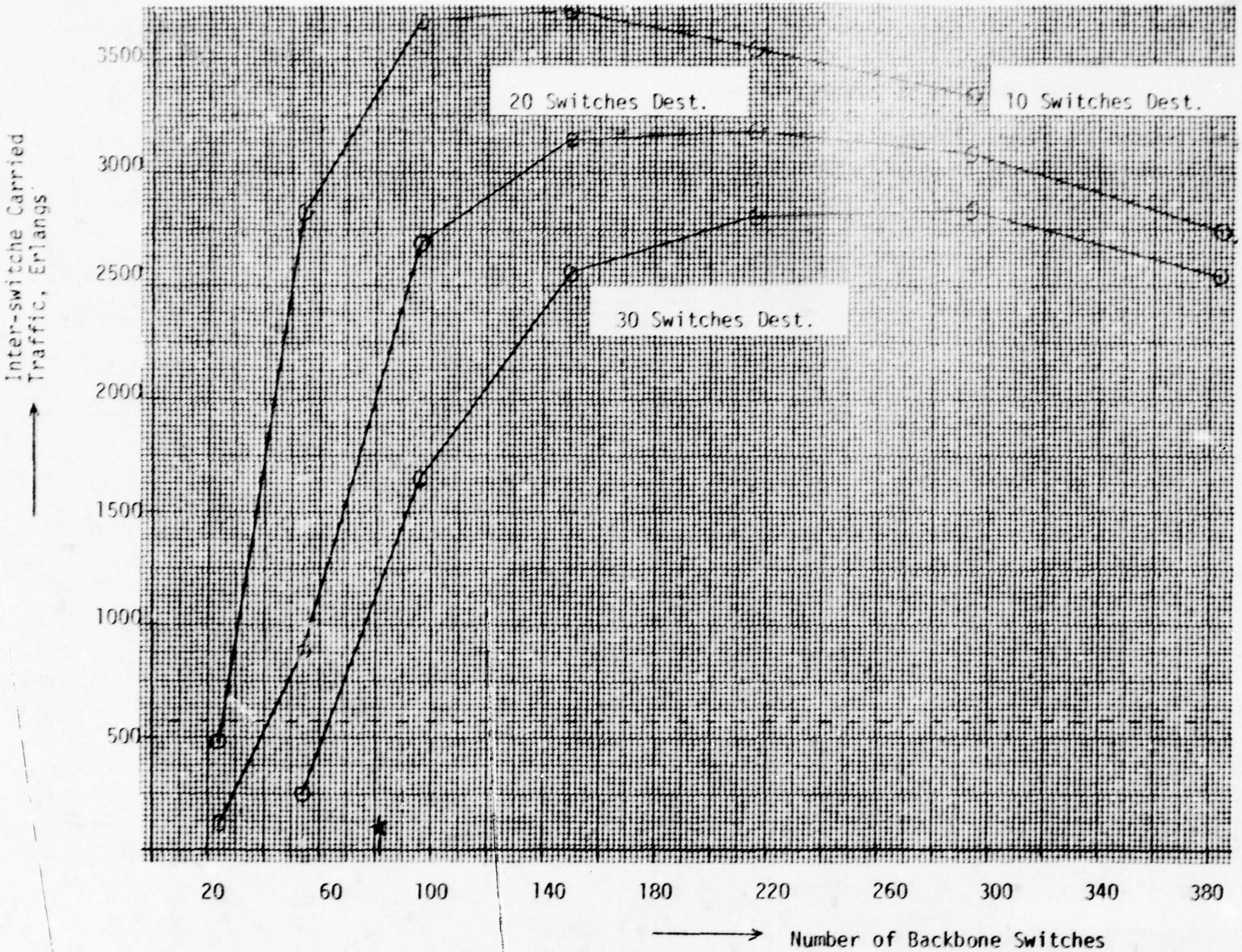


Figure D-8. Operational Traffic Carrying Capability of Alternative 5

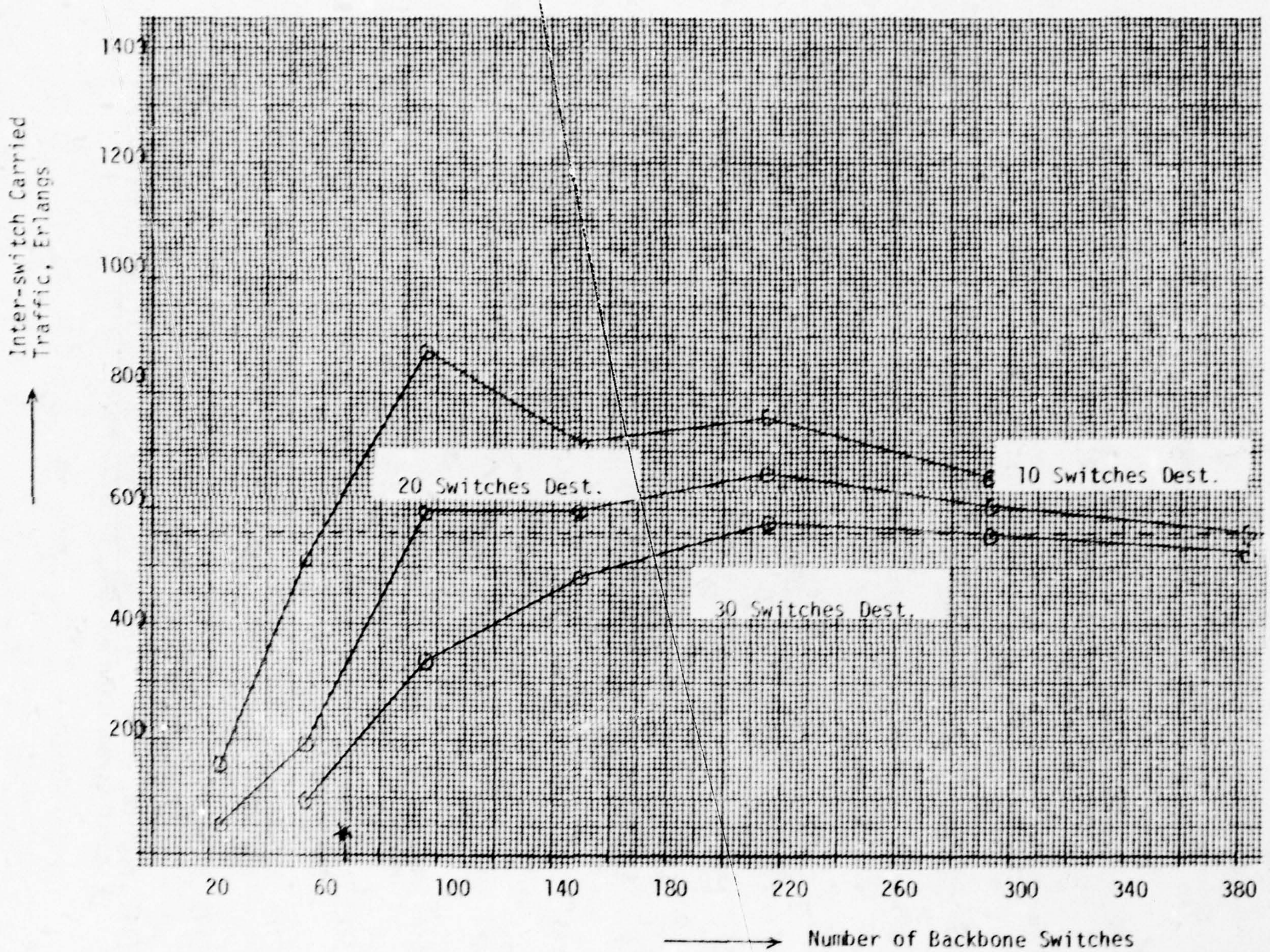


Figure D-9. Operational Traffic Carrying Capability of Alternative 6

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APPENDIX E

NETWORK MANAGEMENT IMPLICATIONS

TABLE OF CONTENTS

		Page
I.	INTRODUCTION	E-1
II.	REAL TIME NETWORK MANAGEMENT	E-1
III.	COMPARISON OF AUTOVON ALTERNATIVES	E-2
IV.	CONCLUSIONS	E-3

APPENDIX E
NETWORK MANAGEMENT IMPLICATIONS

I. INTRODUCTION

Technological improvements in communications have been aimed at getting the calls through automatically. More sophisticated switching machines have been developed over the past thirty years. Automatic alternate routing progressively directs a call through several routes when the primary route is blocked. The present CONUS AUTOVON has been designed with a versatile routing plan known as Polygrid Routing in order to provide maximum connectivity after telephone plant facilities have sustained extensive physical damage.

There are times, however, when the automatic network features are not able to handle the traffic imposed upon them. Present switching machines have some built-in capabilities to control and redirect overload traffic, which are termed network management controls. Traditionally, these controls have been applied manually. But the complexity and required speed of response have led to the development of limited automatic controls on modern switching machines.

Automatic network management controls have traditionally been broad-gauge, which has led to manual override by managers in order to introduce efficient selective controls required of the immediate network condition. Emphasis must be placed on the provision of automatic selective controls that allow control actions to be taken only when necessary. These actions are necessary only under abnormal events such as severe local storms, switching machine failures, or catastrophies such as earthquakes or nuclear war.

In such instances, the network management operation assumes a major role in applying various techniques used to maintain maximum call handling capability. National survival may depend heavily on the ability of network managers to hold the network together. In AUTOVON, such a group must be responsive to government requirements when conditions dictate the need for timely actions to insure continuous operation of essential communications.

II. REAL TIME NETWORK MANAGEMENT

One of the features of AUTOVON II involves the use of stored program control (SPC) systems. Such systems use software to direct switching machines in handling telephone traffic. Another feature is the Common

Channel Signaling (CCS) network. This is sort of a central nervous system, used primarily for a rapid transfer of signaling information in setting up calls. This combination of SPC and CCS will provide faster, more reliable communications and will make possible a myriad of new communications services.

These two features, however, will provide the means for real time network management. "Raw" traffic measurements are collected from the various offices in the network and transmitted via the CCS data network to a Network Management Center in order to maintain a real time data base. Network managers are then kept apprised of the system operation, so that in addition to knowing that call attempts are failing, they can find out why calls are failing and can take action to help correct the problem. When action is required by the network managers, the CCS data link is the return path to the switching machines. Pre-programmed operations might be initiated, for example, to take advantage of variations of traffic loading by utilizing idle trunks in non-busy hour time zones in order to complete more calls in a busy hour time zone. Or, in the case of natural disasters or hostile attack, network managers could initiate measures to control the calls into the affected area or reroute facilities to bypass it. The man-machine interface for this remote control mechanism is again over the CCS data channel to the stored program in each switching machine. This electrically alterable software is the key to dynamic network administration. Network management, then, encompasses the techniques and organization to insure optimum use of available facilities in the face of abnormal loads or equipment or facility failure.

III. COMPARISON OF AUTOVON ALTERNATIVES

Selection of Network Management can be simplified or it can be complicated by the basic alternative and configuration selected. It can be simplified by the employment of a single manufactured switching center or it can be complicated by utilizing a multi-carrier network - either transmission or switching.

Alternatives 1 and 2 present essentially the same network configuration as does today's CONUS AUTOVON. However, Alternative 1 only upgrades the reporting system through the CCS data link. Data collection may be made easier but network control capabilities remain the same. The switching machines have not been altered. Alternative 2, however, promises a large improvement over today's management system. Alternative 2 changes the switches to electrically alterable SPC and adds CCS. Data collection is now received at a Network Management Center on almost a real time basis and the switches are capable of responding to remotely generated instructions, all transmitted over the CCS channel. As in today's CONUS AUTOVON, one centralized management center can effectively control the entire network.

Alternatives 3 and 4 essentially have two networks; one on the DDD and one on a dedicated net. In this study the dedicated switches are considered to be placed at existing switch locations, so network management could continue to operate from one control location. If, under actual implementation, the dedicated network were placed at other locations, it is conceivable that network management could be divided between two groups. It does not appear to be an irreconcilable problem, however. The dedicated network could remain under control of DCA management.

Alternatives 5 and 6 place many small switches on posts, camps, and stations. Network management is complicated by an increase in the number of switches to be managed and by the fact that the switches would be for the most part located in remote areas where facilities would be scarce. Network management is further complicated by the configuration - many trunk groups of small cross sections and a complicated routing plan, because of the topography. Alternative 6, as in two other alternatives, presents two separate networks. In this alternative, there is a satellite network and a terrestrial network. This could lead to a divided management or possibly an expensive single management system. The TDMA satellite system might be a package of service and management and not be associated in any way with the terrestrial overlay.

Thus, management could be by two separate organizations. A combined management organization could be provided - at a price - but there would probably be layered network management between this group and the separate networks. At best, Alternative 6 would present a complicated scheme for managing the network.

IV. CONCLUSIONS

Alternatives 3 and 4 offer the most attractive management configuration, strictly through use of a smaller network. Alternatives 5 and 6 are the least attractive. They are a large decentralized networks which could contribute to further problems of switching equipment diversification and ownership in place. Alternatives 1 and 2 continue the management procedures in use today.

APPENDIX F

ATTRIBUTES OF THE NEXT GENERATION CONUS AUTOVON

TABLE OF CONTENTS

		Page
1.	INTRODUCTION	F-1
2.	DISCUSSION OF SYSTEM ATTRIBUTES	F-2

LIST OF ILLUSTRATIONS

Figure	Title	Page
F-1	SURVIVABILITY	F-6
F-2	DISTRIBUTED OR CENTRALIZED CONTROL	F-7
F-3	NETWORK ADMINISTRATION	F-11
F-4	THE ADVANTAGES OF AN INTEGRATED DIGITAL NETWORK	F-12
F-5	CONUS AUTOVON MIX OF MEDIA	F-15
F-6	SUBJECTIVE EVALUATION OF CIRCUIT QUALITY FOR VARYING AMOUNTS OF CIRCUIT LOSS AND NOISE LEADING TO LISTENER RATING OF "GOOD OR BETTER."	F-21
F-7	NOISE-LOSS GRADE OF SERVICE OF SWITCHED NETWORK WITH EVOLVING DIGITAL FACILITIES AS A FUNCTION OF CONNECTION DISTANCE	F-21
F-8	SIMPLIFIED CONFIGURATION OF ANALOG, DIGITAL AND INTERFACE FACILITIES AS PARTS OF THE SAN AND SDN	F-24
F-9	INTERFACE TERMINALS BETWEEN SDN AND OTHER COMMUNICATION NETWORKS	F-24
F-10	MASTER-SLAVE TIMING STRUCTURE	F-29
F-11	TIMING OF CHANNEL BANKS AND LOCAL DIGITAL SWITCHES WHEN CONNECTED TO THE DT	F-29
F-12	DIGITAL ELEMENTS OF FUTURE CONUS AUTOVON INTEGRATING AUTODIN, AUTOSEVOCOM AND SPECIAL PURPOSE NETWORKS	F-30

LIST OF TABLES

Table	Title	Page
F-I	AVAILABLE EQUIPMENTS	F-3
F-II	OPERATIONAL DIRECTION OF THE CONUS AUTOVON	F-9

APPENDIX F

ATTRIBUTES OF THE NEXT GENERATION CONUS AUTOVON

I. INTRODUCTION

The purpose of this appendix is to provide details of the DCEC postulated System Design Concept for reviewers of TR 18-78 interested in examining the proposals in greater depth. It must be pointed out that this appendix is not an architecture nor a true precise target system. It should be regarded as one example of many possible scenarios. However, the attributes discussed should stimulate a dialog among those who may be involved in planning and implementing the Next Generation CONUS AUTOVON such that the concepts can be scrutinized carefully by specialists of various disciplines.

The discussion on the attributes of The Next Generation CONUS AUTOVON is organized as follows:

1. Digital vs Analog Elements
2. Off-the-Shelf vs U.S. Government developed hardware, software and firmware
3. Lease vs Buy
4. Survivability
5. Operational Direction by the DCA
6. Network Administration and Management Control by the DCA
7. Integrated Transmission, Switching, Technical Control, and Terminating Facilities
8. The AUTOVON Mix of Media vs Backbone Trunking and Access Lines
9. Cost Sharing Responsibilities, DCS vs Military Departments
10. Features, Services, and Network Characteristics
11. Message Channel Objectives, Standards, and Criteria
12. AUTOVON Services for Secure Voice and AUTODIN

II. DISCUSSION OF SYSTEM ATTRIBUTES

1. Digital vs Analog Elements. The digital versus analog elements of the next generation CONUS AUTOVON may be exemplified by the type of equipment listed in Table F-I.

The examples of hardware, firmware, and software listed in the table are not meant as endorsement of the manufacturers. They are only intended to demonstrate that much of the types of equipments which make the Next Generation AUTOVON possible are already readily available in 1978 in the case of terrestrial transmission and switching.

Satellite transmission facilities in the 12-14 GHz range will make possible small, economical satellite terminals which can be located on customer premises such as posts, camps, and stations, but may not be available until 1981.

The rapid proliferation of the No. 4 ESS, digital end offices, and PBX's indicates a strong digital trend as of 1978 such that extensive digital switching facilities will be available for leasing services by 1992.

The evidence that digital switching is undergoing rapid introduction is demonstrated by the following events:

- The Bell Telephone Laboratories (BTL) is currently developing the No.5 ESS Class 5 digital switching machine as a possible substitute for the No.1, 2, and 3 ESS. The implementation of the No. 4 ESS is well underway and there will be nearly 90 of them operational by 1982.

- (GTE) Automatic Electric, Inc., has announced the GTD No.5 EAX and remaining members of their digital family, thus populating the vacancy between their PBX (GTD 120) and the No.3 EAX. GTE sources indicate that by 1982, all new PBX's will be digital; by 1990 all local switches will be stored program control and 90% will be digital.

- United Telephone, an Independent telephone company, expects to be 50% digital by 1988.

- Continental Telephone, another Independent telephone company, has made a massive commitment to go digital in a five year plan. Continental has 1800 central offices, 90% of which are step-by-step machines, and of which 20% are manufacturer-discontinued systems.

TABLE F-I. AVAILABLE EQUIPMENTS

TYPE	EXAMPLE	ANALOG VS DIGITAL
SWITCHING:		
TANDEM	No. 4 ESS (WESTERN ELECTRIC)	DIGITAL
	3EAX (GTE)	DIGITAL
	DMS 200/300 (NORTHERN TELCOM)	DIGITAL
	DSS (ITT NORTH ELECTRIC)	DIGITAL
	DTM (STROMBERG CARLSON)	DIGITAL
END OFFICE (LOCAL)	ITS (TRW VIDAR)	DIGITAL
	SYSTEM CENTURY DCO (STROMBERG CARLSON)	DIGITAL
	SYSTEM 12 (ITT)	DIGITAL
	DMS 10, 100 (NORTHERN TELCOM)	DIGITAL
PBX	SL-1 (NORTHERN TELCOM)	DIGITAL
	580L (WESCOM)	DIGITAL
	ROLM	DIGITAL
	GTD 120 (GTE)	DIGITAL
TRANSMISSION:		
METALLIC AND/OR OPTICAL FIBERS	T1 CARRIER (VARIOUS MANUFACTURERS)	DIGITAL
	T2 CARRIER (VARIOUS MANUFACTURERS)	DIGITAL
MICROWAVE LONG HAUL	TD-2 MICROWAVE (AT&T INTERCITY TRUNKING)	ANALOG WITH DIGITAL DUV T1 COMPATIBLE
SHORT HAUL	DRM 2-6 (TRW VIDAR)	DIGITAL
SATELLITE	SBS*	DIGITAL
	ADVANCED WESTAR (WESTERN UNION)*	DIGITAL
	ADVANCED COMSTAR (AT&T)**	DIGITAL

* AVAILABLE 1981

** AVAILABLE 1983

It is planning replacements along the following schedule: 40 in 1979, 80 in 1980, 100 in 1981, 150 in 1982. By 1982, Continental will have 48,000 digital trunks, and 50,000 digital lines.

- The Rural Electrification Administration (REA) reports that approximately 100 digital switch contracts will be approved by 1978.

- Bell of Canada will not use the U.S. Bell System's CCIS (which is analog oriented and will instead leap-frog to the CCITT No. 7 (which is digital oriented).

Furthermore, of the 17,000 central offices in the United States, 42% are step-by-step (analog). The driving forces to mechanize operator services, the regulatory requirement to provide measured services, and rapid growth (which calls for more building space) will call for large capital expenditures if the analog switches are retained. Provision for these features and characteristics are trivial with digital switches. Hence, there appears to be a critical period in the 1980-85 time frame, which should offer a key to DCA, regarding the pace of digitization. If the Bell System opts to resolve these problems by digitization, the general availability of digital switching will undergo an explosive growth in the early 1980's.

The primary motivation for the use of digital switching and transmission for the Next Generation AUTOVON are:

- Consonance With Developments in Large Scale Integration

The sharply declining costs of digital large scale integrated circuits exemplified by microprocessors, programmable logic arrays and memories when compared to discrete integrated circuits, are expected to continue declining into the 1980's. The caution: firmware and software costs can be extremely high unless amortized over a large number of units of a product.

- Economy

Provided that large quantities of a given product are in demand, large economies of scale are possible with digital hardware, firmware and software.

- Reliability and Maintainability

By exploiting the reliability of large scale integration vs. discrete components, and the use of redundancy in certain areas,

extrapolated mean-time-between total failures approaching 1 hour in forty years have been reported for certain digital switches. Even with generous bounds for error, this represents orders of magnitude improvement over analog techniques of the 1960's used in the current CONUS AUTOVON.

The reliability of T1 lines over paired cable has been clearly demonstrated with over 15 years of experience by the commercial carriers.

- Remote Performance Monitoring

By automatic monitoring of bipolar signals and framing bits of the T1 line, commercial carriers have demonstrated that remote performance monitoring techniques have been greatly improved over analog techniques of the 1960's.

- Ease of Protection and Encryption

The rapid proliferation of digital switching and transmission allows for economical means for encryption and protection as AUTOVON evolves.

2. Off-the-shelf versus U.S. Government Developed Hardware, Software, and Firmware. As indicated in Table F-I, the hardware for the Next Generation CONUS AUTOVON is already available, or will be available in the early 1980's. As such, there is no need for DoD-sponsored hardware development.

However, depending on the features required by future users of AUTOVON, and depending on DCA's requirements for exercising operational direction and management control, the following firmware and software may require DoD funding or development. In many cases, modification of commercial software and firmware may suffice.

Firmware and software for:

- Dynamic routing of services in crisis and war to support DCA's mission in operational direction.
- Automatic message accounting for DCA's use in management control (Network Administration).
- Assuring dynamic stability, bit count integrity, timing & synchronization, particularly across the PBX/End office boundary.
- Interfaces with the existing AUTOVON during hybrid operation.
- Interfaces between PBX's and the small, collocated satellite terminals operating in TDMA.

3. Lease vs Buy. In accordance with DoD directives, most of the Next Generation CONUS AUTOVON will be leased. However, it will be incumbent upon the DCA to have some assurance that the rapidly declining cost per circuit mile and the cost of erlang switched being experienced by commercial and specialized carriers are shared by the DoD.

Leasing of available services and facilities, with proper management, should enable the DoD to:

- Avoid long lead times necessary in the DoD developed hardware, software, and firmware required in weapons systems acquisition.

- Exempt commercial CONUS communications from costly military specifications relevant to combat-oriented telecommunications.

- Allow changes to exploit new commercial technological developments within the constraints of termination liabilities.

4. Survivability. The remote switching units and PBX's that are being marketed are so small in size that they can easily be placed within the confines of a hardened facility wherever the user warrants such hardening. (See Figure F-1).

Instead of dual-routed dedicated circuits or dual homing on AUTOVON switches, multiple homing to an AUTOVON Mix of Media is postulated for the Next Generation CONUS AUTOVON.

The postulated mix of media would consist of:

- Collocated Satellite Terminals

- Access to one or more of the 15,000 end offices in the United States and to more than 100 No. 4 ESS machines which are rapidly being installed by the AT&T.

- T1 tie trunks to nearby base central offices.

- T1 interconnects to a regional AUTOVON access switch exemplified by the No. 1 ESS at the Pentagon.

5. Operational Direction By the DCA. The postulated Next Generation CONUS AUTOVON will call for improved responsiveness of the DCS in meeting the needs of the National Command Authority (Figure F-2). In the current AUTOVON real time reconfiguration of the networks is accomplished by AT&T via a facility at Drainesville, Virginia, with status reports submitted to the DCA Operations Center in Arlington, Virginia.

The essence of the function commonly called the operational direction of the DCS and AUTOVON may be summarized as shown in Table F-II.

ATTRIBUTES OF THE NEXT GENERATION

CONUS AUTOVON

SURVIVABILITY

- ACCESS TO VIRTUALLY THE ENTIRE TELECOMMUNICATIONS RESOURCES OF THE CONTINENTAL UNITED STATES IN TIME OF CRISIS OR WAR (IN CONTRAST TO DEDICATED POLYGRID OR DEDICATED CIRCUITS.)
- REMOTE SWITCHING UNITS AND EPBX'S COLLOCATED WITH USERS WOULD BE AS SURVIVABLE AS THE USERS.

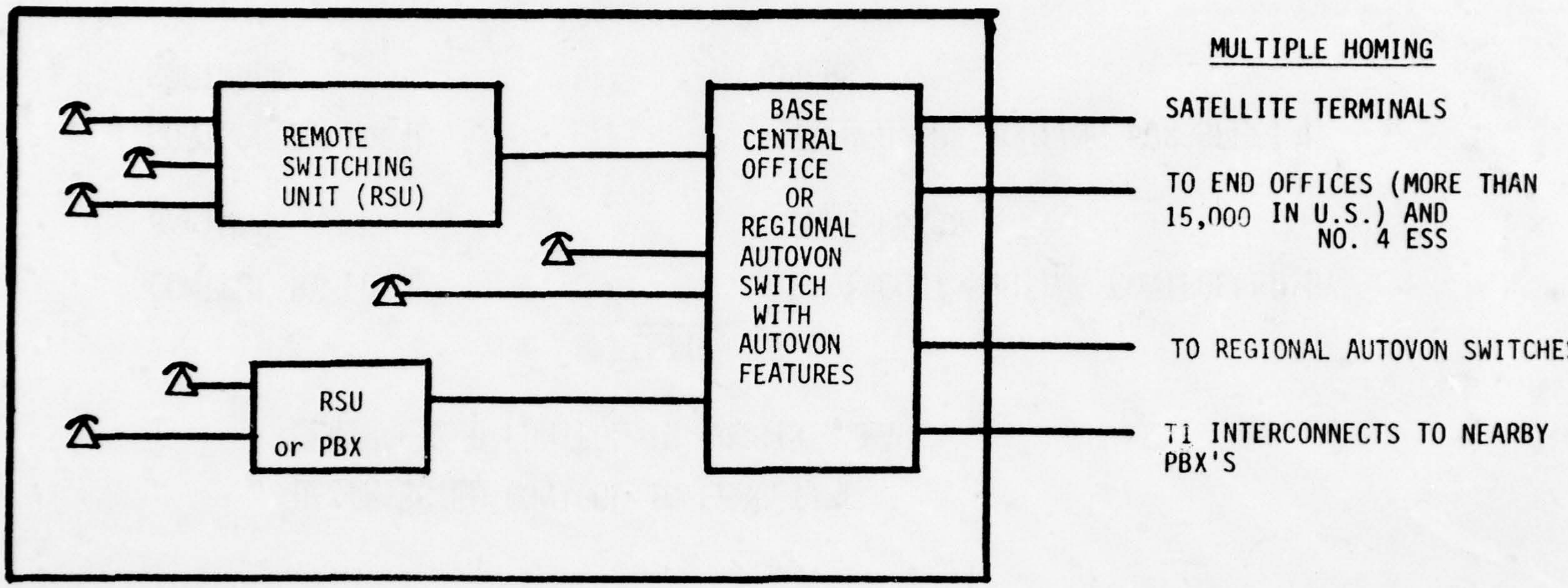


Figure F-1. Survivability

ATTRIBUTES OF NEXT GENERATION
CONUS AUTOVON

DISTRIBUTED CONTROL IN PEACETIME
CENTRALIZED CONTROL IN CRISIS & WAR

- PEACETIME

CONTROL BY LOCAL SOFTWARE	LEAST COST ROUTING CONTROLLED BY LOCAL PBX'S
CONTROL BY LOCAL SOFTWARE	"NAILED UP" ROUTING FOR SPECIAL USERS

- CRISIS & WAR

CONTROL BY DCA SOFTWARE	DYNAMIC "NAIL UP" UNDER CONTROL OF JCS - J3 AND DCAOC

Figure F-2. Distributed or Centralized Control

TABLE F-II. OPERATIONAL DIRECTION OF THE CONUS AUTOVON

Situation	Description of Control	Availability
• Peacetime		
Least Cost Routing	Control by Resident Firmware and Software at Local Central Office on Post, Camp, Station	Available with Off-the-Shelf PBX's and End Offices.
Special Purpose Users and AUTOVON 4-Wire Users	Dedicated Time Slots Under Control of Resident Firmware and Software at Local Central Office on Post, Camp, Station	Available with Off-the-Shelf PBX's and End Offices. Available with No.4 ESS/
• Wartime or Crisis Conditions		
Control by DCA in accordance with modified DCA Operational Direction Role & Mission	Centralized Control exercised by DCA's DOCC Complex upon direction from JCS-J3 and the National Command Authority. Dynamic Dedicated Time Slots Exercised Via the Bell System's No.4 ESS Network.	Software and firmware not available. Possibility of modified software for related applications by AT&T for communications during natural disasters.

6. Management Control (Network Administration). The postulated Next Generation CONUS AUTOVON will call for improved management control (Network Administration) by the DCA to monitor the lowest possible leasing costs within the constraints of the then current survivability considerations.

Traffic data relevant to reconfiguration of the interswitch trunks and access lines and occasional switch closures are primarily derived from reports from the AT&T at present.

The implementation of automatic message accounting systems was considered too costly at the time that the current CONUS AUTOVON was implemented. However, the cost of such systems with many new features has dropped dramatically within the past few years and these systems are routinely offered by vendors of digital PBX's and end offices.

By purchasing or leasing such systems at post, camp, station, and central offices, the DCA could perform its management control much more effectively at a modest cost see Figure F-3. Periodic traffic and cost data to be specified by the DCA Operations Directorate could be reviewed by analysts with cost and survivability being the dominant considerations. The AUTOVON Mix of Media available to the local central offices could be effected by DECCO.

7. Integrated Transmission, Switching, Technical Control, and Terminating Facilities. In the postulated Next Generation CONUS AUTOVON, the digital switches would not only perform the functions normally associated with conventional central offices, PBX and Centrex switches, and tandem switches, but they would also perform the functions associated with patching, testing, and monitoring, and wiring associated with technical controls and terminating facilities.

The top string of blocks in Figure F-4 [1] shows the relationship of the multiplex equipments, channel banks, toll terminating facilities, trunk relay circuits and analog switches as configured in the current AUTOVON network. All elements to the left of the "x" representing the main distribution frame (MDF) are located in what is called "technical controls" in DCA terminology. In the commercial world, these elements are maintained by the trunk maintenance force and all elements to the right of the MDF by the equipment (or switch) maintenance force.

Note that when digital switching and digital transmission are combined, as depicted by the bottom line of the figure, most of these elements are eliminated. In terms of original investment cost, the facilities eliminated represent several hundred thousand dollars worth of assets. Because original investments are reflected in tariff charges, elimination of such assets should be reflected in lower charges to the customer. The DCA should assure itself that such is the case in future CONUS AUTOVON charges.

ATTRIBUTES OF NEXT GENERATION
CONUS AUTOVON

NETWORK ADMINISTRATION VIA AUTOMATIC MESSAGE ACCOUNTING SYSTEMS

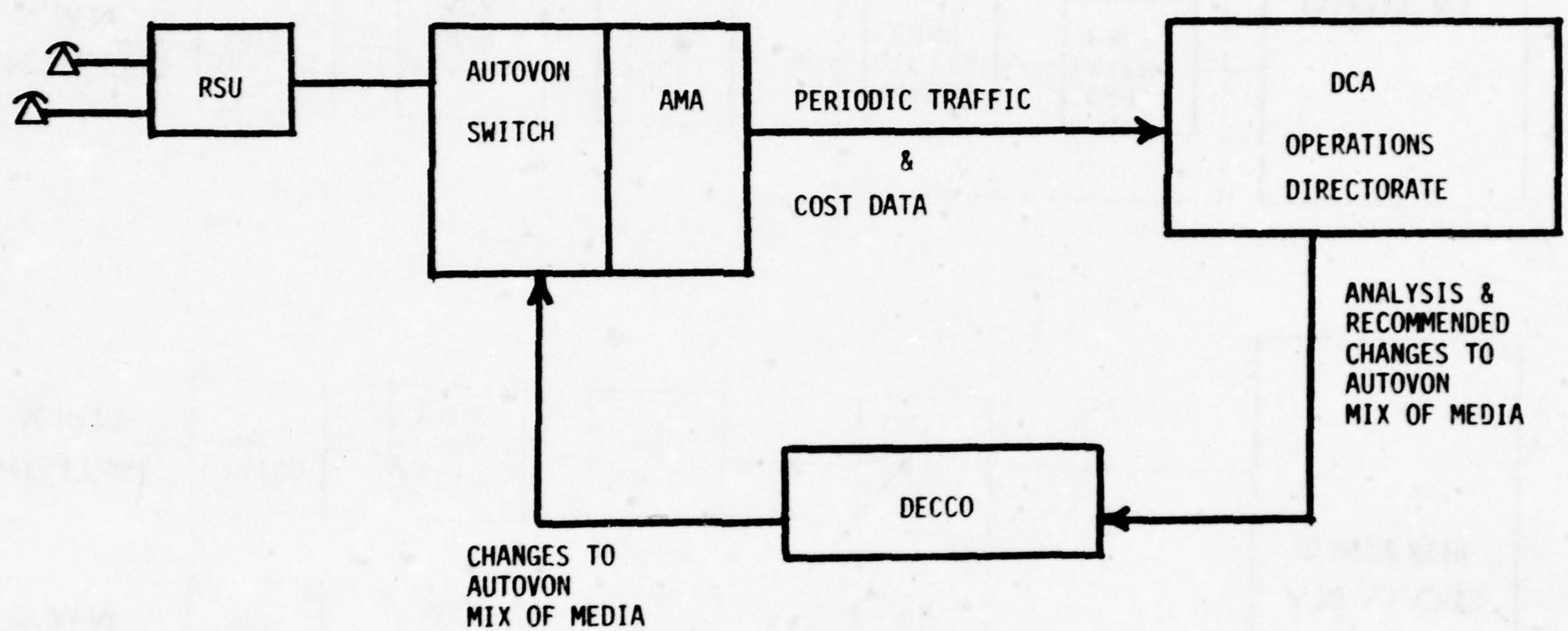


Figure F-3. Network Administration

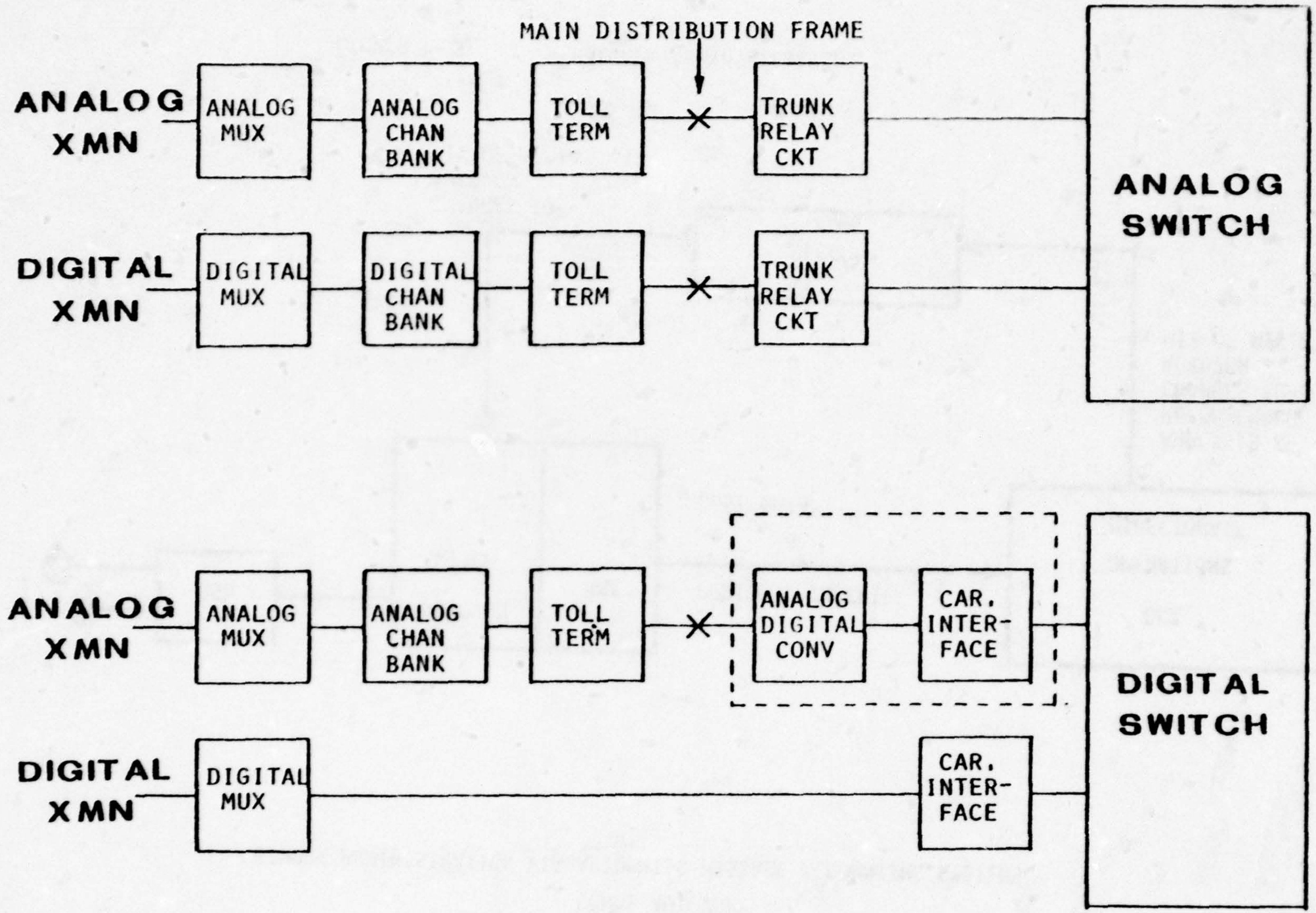


Figure F-4. The Advantages of An Itegrated Network

Furthermore, in the commercial world, when the all digital configuration is attained, the trunk maintenance and equipment maintenance forces are combined, thus achieving major savings in maintenance cost. These costs are also reflected in tariff charges, and the DCA should assure itself that such savings will be reflected in future tariffs.

However, during an interim hybrid period, the configurations represented by the two middle lines of the figure will be the case in the real world. The figure also shows, then, that a transition to the bottom line configuration is achievable on an evolutionary basis and such a strategy is being pursued in the commercial world.

(1) Dedicated Circuits vs "Dedicated Time Slot". In the older toll terminating facilities in commercial telecommunications, and the technical controls in the U.S. Government-owned facilities, dedicated circuits are hard-wired at distribution frames. Alternate routing is accomplished manually at patch bays with patch cords.

With the new digital switches, dedicated time slots can be "nailed up" under firmware or software control of the digital switches. There is no reason why they cannot be as reliable as hand-soldered or wire-wrapped connections at a frame. Nor are they less reliable than patch cords and patch jacks which themselves may become worn and intermittent with frequent use.

Even in the case of dedicated circuits over the lines in the current Bell System, metallic pairs are not individually dedicated to the dedicated user. Many of the most critical special purpose circuits are already sharing two pairs of copper wire with up to 23 other users and are being carried over "dedicated time slots".

"Dedicated time slot" connections will undoubtedly create some uneasiness among dedicated users because they appear to be a switched connection, but in actual fact, they could be just as, or more reliable than, dedicated circuits using the technology of the 1960's. All digital switches on the market today are capable of "dedicated time slot" service, thus performing the functions of an automated patching and wiring facility.

(2) Patch Bays, and Terminating Facilities (Conditioning Equipment). In older commercial facilities and U.S. Government-owned technical controls, each circuit requires terminating facilities such as single frequency (SF) signaling units, pads, amplifiers, echo suppressors and the like. In Figure F-4, these are lumped together in the block labeled "Toll Term" (for toll terminating). In the 1960's, such technical controls, including associated channel banks, were arranged as depicted in the top line of Figure F-4. In the Bell System's digital No. 4 ESS, wherever direct T1 interfaces are implemented, the patch bays and much of the toll terminating facilities have been eliminated, as depicted in the bottom line of Fig. F-4. This is is also true with digital end offices with T1 lines interconnecting to remote switching units.

These techniques are rapidly being employed in the No.4 ESS facilities, digital end offices, and digital PBX's as of 1978. It would therefore seem reasonable to assume that the Next Generation CONUS AUTOVON will integrate the functions of channel banks in multiplexers, terminating equipments, and many of the audio frequency patch bays that are familiar to the military communicator in Government-owned technical controls. They can be operated with far less personnel per circuit terminated or per erlang switched.

(3) Testing of Digital Facilities and Data Services. The AT&T and the U.S. Independent Telephone Association (USITA) have already developed a wide range of hardware, software, and firmware standards and procedures, and automated test equipment in connection with the Bell System Digital Data Service (DDS) offering. Although much of this applies to data services over analog facilities, considerable work has already been accomplished and tested in the market place for application over T1-oriented facilities. There is no reason why much of this cannot be applied to the Next Generation AUTOVON for providing "dedicated time slot" data services.

Many of these techniques involve automatic loop back testing for rapid trouble isolation from hub offices (remote from the customer's premise) and for rapid restoral and alternate routing.

Such techniques can be adopted in the Next Generation CONUS AUTOVON on a leased service basis without incurring heavy development costs on perceived military-unique requirements.

8. The AUTOVON Mix of Media vs Backbone Trunking and Access Lines. The transmission media for the current AUTOVON consist of interswitch trunks (voice channels) and access lines (voice channels) which are dedicated to AUTOVON and not accessible for message telephone service (MTS or telephone service for the general public). This also implies that the total vast resources of the Bell System and the Independents are not available to AUTOVON users, particularly, the 4-wire subscribers who enjoy the benefits of MLPP.

The postulated Next Generation CONUS AUTOVON takes advantage of virtually the entire telecommunications resources in the Continental United States as depicted in Figure F-5.

The figure also highlights the advantages of each element of the Mix of Media. Current plans of satellite carriers who plan to offer small satellite terminal services in the 12-14 GHz spectrum promise economical services even over less than transcontinental distances, and economical services which require multi-megabit transmission. The Bell System is forecasting a great number of additional features via its network of No.4 ESS and CCS. It has recently committed itself to the development of the No.5 ESS for digital switching services in the

ATTRIBUTES OF NEXT GENERATION

CONUS AUTOVON

- SATELLITES
  - VERY LONG DISTANCE TRANSMISSION AT LOW COST
  - MULTI-MEGABIT TRANSMISSION
- NO. 5 ESS, NO. 4 ESS/TD-2 MICROWAVE, L-5 CARRIER
  - LONG AND MEDIUM TRANSMISSION AT LOW COST
  - FLEXIBLE COMMUNICATIONS IN CRISIS & WAR
- T1 LINES/METALLIC OR FIBER OPTIC
  - SHORT DISTANCE TRANSMISSION AT LOW COST
  - LOW COST DATA TRANSMISSION UP TO 56 KBS
- REGIONAL AUTOVON SWITCHES/T1 LINES
  - ECONOMICAL IN CERTAIN REGIONS WITH CLUSTERS OF DOD USERS

Figure F-5. CONUS AUTOVON Mix of Media

exchange areas. With more than 15,000 of these end offices in the United States, it would be prudent to assume that conversion to digital operation here would require an extended period of time past the 1982-1992 period of interest. Regional switches are postulated where economical in the Next Generation CONUS AUTOVON. The locations could be identifical to those being sponsored under the Defense Metropolitan Area Telephone Systems (DMATS).

9. Cost Sharing Responsibilities, DCS Versus Military Departments. In the current CONUS AUTOVON, a form of industrial funding is utilized for the DCS backbone trunking and the leasing of the switches via the SCAN tariff. However, the Military Departments must fund for the access to the network, including hardware required to meet the AUTOVON Interface Criteria. This arrangement motivates the Military Departments and other users to minimize access line charges at some sacrifice to the overall grade of service of the AUTOVON Network. In view of the fact that the average access line is over 88 miles (142 km) in length, there is a compelling motivation to cut this cost. Indeed, the DCEC studies have shown that the access line charges will easily become an even heavier burden if the current AUTOVON configuration is retained.

In the future AUTOVON, it is imperative to explore ways in which the cost burdens can be shared equitably without sacrificing grade of service to the users.

The postulated Next Generation CONUS AUTOVON has "pushed" the "smarts" or "intelligence" into the posts, camps, and stations that have historically been the domain of the Military Departments.

Let us postulate that the commander of the post, camp, or station retains his responsibilities of all telecommunications that does not leave the confines of his base. The leasing of such services (or use of U.S. Government-owned facilities) would be retained as his prerogative.

The industrially funded DCS portion would involve the software and firmware required at his Central Office for entry and exit to the Next Generation CONUS AUTOVON. DCS funding would also be called for on any devices such as privacy or encryption devices which are installed because of national (as opposed to local) interest.

Any individual AUTOVON special purpose service which the post provides motivated by the needs of the tenants of the post, would be provided by the Military Department.

The post commander would retain control of least cost routing features available in the new digital PBX's and end offices in peacetime, thereby allowing him to obtain the most economical long-haul services. The least cost routing features would allow him access to the AUTOVON Mix of Media and the commercial system, whichever is more economical.

The DCEC analysis shows that his access line charges will be reduced compared to present charges.

Special purpose users of "nailed up connections" would be charged up to the point of interconnection to the AUTOVON Mix of Media at rates set by the leasing vendor for leased services, or be provided by post T1 facilities on U.S. Government-owned facilities.

In short, the industrially funded portion of CONUS AUTOVON would fund for:

- The AUTOVON Mix of Media including:
  Satellite terminals and services
  Services associated with the Bell System's No.5 ESS and No.4 ESS, and Independent digital Class 5 Offices
  Services Associated with Regional AUTOVON switches
  T1 interconnects to neighboring Central Offices
  Software and Firmware add-ons to the base digital Central Office associated with the AUTOVON Mix of Media
  Privacy or encryption devices dictated by National Policy.

- The Military Department and the Post Commander would fund for:
  The procurement or leasing of digital switching facilities and T1 line hardware.
  The software & firmware associated with features desired for post communications.

10. Features, Services, and Network Characteristics. In the current CONUS AUTOVON network provision of special features and services (or the "smarts" or intelligence) of the network are provided by the backbone switches. The backbone switches provide the following special features:

- Multi-level Precedence Preemption (MLPP) - Precedence is a method of call classification used by the customer on all communications. There are five levels of precedence, designated four (4) through zero (0). Precedence level four (4) is used for normal routine calls. Precedence level zero (0) is the highest ranking precedence. Preemption is the right of seizing and using the equipment on preference over subscribers assigned a lower precedence. Those having this privilege can obtain access to available circuits in preference to other subscribers; and, where all circuits are in use, the higher precedence may force a caller of lower precedence to relinquish circuits required to complete the call. The precedence level of a call can be selected by the caller.

- Conferencing - arrangements are in two main categories: automatic (or preset) and random (or selective) conferences.

Automatic conferencing permits an authorized subscriber to be connected simultaneously to a predetermined, fixed group of subscribers. Each preset conference is assigned a level of precedence as authorized.

Random conferencing permits a subscriber simultaneous connection to two or more subscribers. The originator of the conference can choose conferences at random.

• Off-Hook Service - a subscriber upon lifting the handset of his telephone is immediately connected to a predesignated subscriber.

• Precedence Alerting - AUTOVON backbone switches provides a distinctive audible and/or visual signal to indicate whether an incoming call is of PRIORITY or higher precedence.

• Automatic Traffic Overload Protection - This control functions at a predetermined traffic load level to reduce or exclude all originations from subscribers identified by the customer as being subject to this control.

(1) Current AUTOVON Features Versus Off-The-Shelf Features. By utilizing commercial off-the-shelf hardware and modified off-the-shelf firmware/software, it is technically feasible to provide most of these features and a host of other features at switch or concentrator locations closer to the subscriber. The basic technology which has made this possible is the large scale integrated circuit without which digital switching would be impractical. The number of components is increasing 100% per year with the number of functions already surpassing the one million mark.

These developments have made it possible to find on the commercial market, switches that could easily perform the features listed above or equivalent features at the PBX or base central office level. As a matter of fact, the rapid advance of this technology indicates that the "smarts" or intelligence" could be located at the user station (telephone instrument) itself some time within the 1982-1992 time frame.

At least one vendor has already made a commitment for the MLPP software package and its cost will be a function of the number of such switches fielded for amortizing the software development. It is also possible (if there is a DoD policy change on this requirement) that a two-level precedence feature could be provided with off-the-shelf firmware/ software, thus amortizing the software development over a large number of switches.

Conferencing features are provided with off-the-shelf digital switches on the market. Priority diversion equivalent service can be provided with off-the-shelf hardware/firmware/software although the exact means of providing this feature may not conform exactly to what is provided by AUTOVON switches today.

Equivalent service may be provided for precedence alerting with what is available on the market. The nature of automatic traffic overload protection will be different in the future. Nevertheless, this feature can be provided with off-the-shelf hardware and software.

In addition to the features noted above, off-the-shelf hardware/firmware/software could provide many additional features including those that are required by special purpose networks today.
Some examples are:

- Voice Message Storage - a call can be stored by the switch for delivery at a later time if the called party is absent.
- One Number INWATS - a single number would be used for a certain function, e.g., the RED CROSS for personal tragedies.
- Remote Call Forwarding - Calls to a called party could be remoted to a location where he may be temporarily located; e.g., for TDY.
- Privacy Service - Calls cannot be easily monitored by unfriendly parties
- Alternate Voice/Data up to 56 kilobits per second - callers who require high speed facsimile, access to computers, and the like.
- Digital connection services for AUTOSEVOCOM, AUTODIN, or special purpose users.

(2) Network Routing Considerations. The hierarchial routing plans used in general message telephone systems were not utilized in the current AUTOVON study, because the DoD requires a system which must complete calls even in times of stress that could eliminate one or more switching centers. A routing control plan, and a unique ploygrid network configuration, were developed for AUTOVON to preserve its survivability.

The polygrid is a pattern of interconnecting trunks spread across the United States. Each backbone switch is interconnected with many other backbone switches by separate trunking paths. A computer-generated alternate routing plan selects the shortest paths wherever possible to make efficient use of the system. However, in case of network damage, a very sophisticated routing plan provides extended routing for precedence traffic. This ignores efficiency but provides the ability to bypass damaged areas of the network. The ploygrid limits the number of inter-machine trunks that must be switched to form an end-to-end connection, so that high quality transmission performance is achieved.

The polygrid network plays a major role in survivability and represents an acceptable method for the rapid and reliable connection of defense communications.

Management of this network requires control of all traffic and of abnormal conditions that can affect trunks and switching centers in the network. All switching center network management controls are directed from a central location, the Network Management Center (NMC).

The operation of the network must be kept under constant, around-the-clock surveillance so that problems may be detected quickly. Once the occurrence of a problem is recognized, its source must be identified to determine whether control action by the Network Management Center is needed. If control action is required, the network status is continually updated by a telemetry system that determines if the controls worked.

In the future CONUS AUTOVON, it would be possible to abandon the DoD-unique polygrid network and utilize commercial hierarchical techniques with extensive use of tie trunks, while providing the inherent survivability of the entire commercial telecommunications plant of the United States.

11. Message Channel Objectives, Standards, and Criteria. By remaining compatible with commercial telecommunications, the next generation AUTOVON could potentially exploit a great deal of research, development, and experience already accomplished. For example, message channel objectives, standards, and criteria have already been formulated by the Bell Telephone Laboratories for an evolutionary strategy in converting the current Switched Analog Network (SAN) to the Switched Digital Network (SDN). Many of the following discussions are actual extracts from work that has appeared in the Bell System Technical Journal regarding this strategy.

(1) Loss Noise Grade of Service. [2] In commercial telephony, the Bell Telephone Laboratories prescribes a variety of message channel objectives based on occasional sampling of the network and determining what objectives may be reasonably achieved within economic constraints. One of the most important of these performance parameters is the loss noise grade of service which contributes heavily in their loss and level design of the network.

Mathematical models of subjective opinions have been developed by Bell Laboratories to predict categories of performance such as the percent of customers who would rate certain transmission impairments as "Good or Better," "Poor or Worse," etc., on a five-point rating scale of excellent, good, fair, poor, and unsatisfactory. Figure F-6 shows the percent "Good or Better" contours versus loss and noise. For example, if a telephone connection has 20 dBrnC of circuit noise and 12 dB of loss, it is estimated that about 90% of telephone users would rate this connection Good or Better.

For the future, as the SDN evolves in the Direct Distance Dial (DDD) network or a future AUTOVON network, the predicted noise-loss grade of service expressed in percentages of subscribers rating transmission quality both "Good or Better" and "Poor or Worse" are illustrated in Figure F-7 [3]. The grade of service is a function of connection distance (airline mileage). The curves shown are smoothed versions of the computed results. The "all-digital toll plant" refers to a hypothetical situation when all voice circuits are carried from end office to end office in digital form

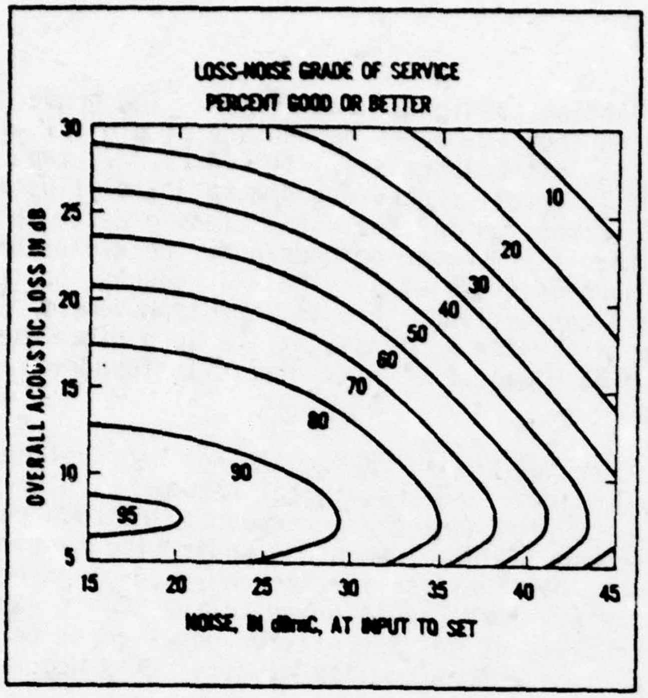


Figure F-6. Subjective Evaluation of Circuit Quality for Varying Amounts of Circuit Loss and Noise Leading to Listener Rating of "Good or Better"

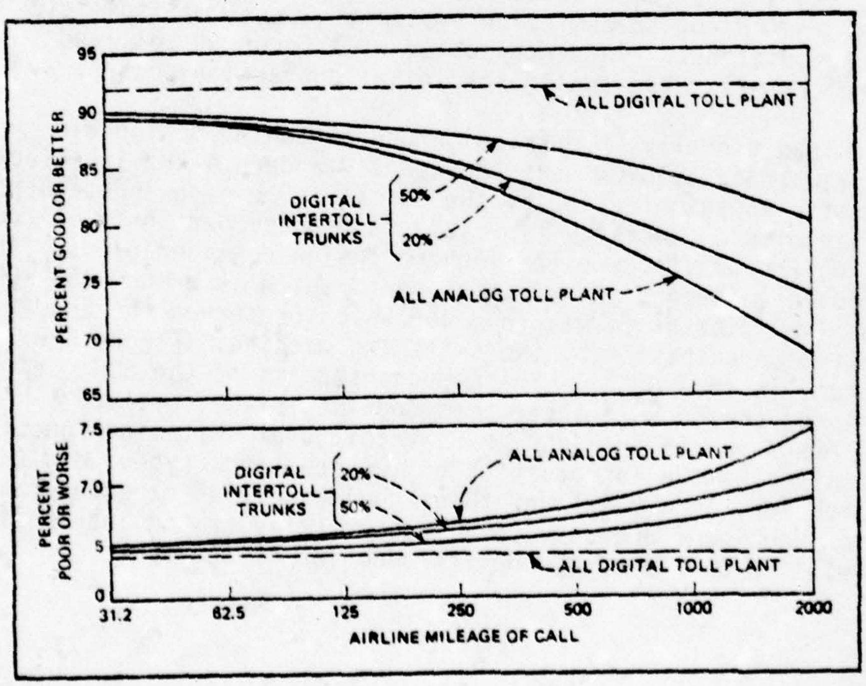


Figure F-7. Noise-Loss Grade of Service of Switched Network with Evolving Digital Facilities as a Function of Connection Distance

without intermediate analog-to-digital conversion. The grade of service is predicted to improve as the percentage of digital connectivity in the toll plant increases. In Figure F-7, two examples (20% and 50% intertoll trunks are digital) are illustrated. The improvement is more substantial for connections greater than a few hundred miles than for shorter connections. The evolution of digital facilities improves grade of service and reduces the contrast between long and short connections; that is, the improvement is greatest where grade of service is least, at the long distances. For the all-digital toll plant case, no contrast is found between long and short calls.

There is no reason why AUTOVON could not use the identical strategy for evolving with and to the digital network with corresponding improvements occuring during an extended transition period. Expenditures for research and development on subjective testing will not be required as was the case for secure voice planning. If the commercial strategy for transitioning to the SDN is adopted by DCA for AUTOVON, quality of service will be equal to or better than current commercial telephone quality of service as demonstrated above.

(2) Digital/Analog Interfaces [3]. Compatibility of the SDN with the SAN is the dominant constraint for the introduction of the No. 4 ESS or other digital PCM based switches and the SDN into the current DDD or AUTOVON network. The SDN is constructed exclusively with digital transmission and switching facilities. In contrast, the SAN is constructed with analog switches and a mixture of digital and analog transmission systems. These two facilities networks are distinct. Interconnection will occur at toll and local wire centers where analog-to-digital conversion occurs.

Traditionally, transmission and switching designs in the DDD network or AUTOVON have adopted a standard 4-kHz interface which permits route selection by the switch to be made independently of the transmission facility type, and to be dependent only on route destination and traffic engineering and design considerations. The SDN introduces a second interface standard which is a mu = 255 PCM word-organized digital format in a way which preserves the traditional method of route selection by the switching machine. Figure F-8 illustrates, in more detail, the component parts of the SDN, and the way 4-kHz and 64 kb/s interfaces coexist in the combined SAN/SDN network. As shown in in Figure F-8, traditional switching functions are maintained by the introduction of two new trunk types, digital and combination. As a result of these choices, it is expected that the basic functional and service characteristics of the intertoll network will be unchanged by the introduction of the SDN.

The selection of a signal format, and loss and level plan, represents a significant change from traditional standards in the network. These choices simplify maintenance level administration and trunk design and minimize the need for digital processing. The significant features are:

- The mu = 255 PCM format of the D2 channel bank becomes a network standard.

- Loss and level administration merge into a unified plan rather than being treated independently as in the past. (For AUTOVON four wire service, slight adjustments would have to be made from the commercial plan which is primarily oriented towards two wire service.)

- A digital milliwatt test signal becomes a standard at all test points in the SDN; furthermore, this test signal is compatible with the analog milliwatt test signal in the SAN.

- The preservation of bit integrity through the network offers opportunities for simplified and enhanced maintenance and the promise of enhanced voice performance.

Direct digital interconnection of digital and combination trunks on No. 4 ESS or digital switches changes facilities utilization in three significant ways:

- Significant economies have been demonstrated by directly terminating the digroup, which is a 24-channel TDM-PCM signal carried on 1.544 Mb/s facilities. These economies are sufficient to eliminate the use of voice-frequency cable in the toll connecting trunk plant and to stimulate the use of Tl-carrier significantly.

- The 24-channel digroup becomes the basic unit in facilities provisioning instead of a single circuit.

- Channel numbering and trunk numbering in switching machines are strongly interrelated because of the sequential nature of the 24-channel word (time slot) organized TDM-PCM digroup. The SDN plan uses the straightforward data base and record administration.

Maintenance of the SDN will be simplified because of the opportunities for automatic error monitoring in digital switches and digital facilities. Significant economies will occur in the maintenance of digital trunks, since a successful test of one digital trunk in a digroup will assure the performance of the remaining 23 trunks.

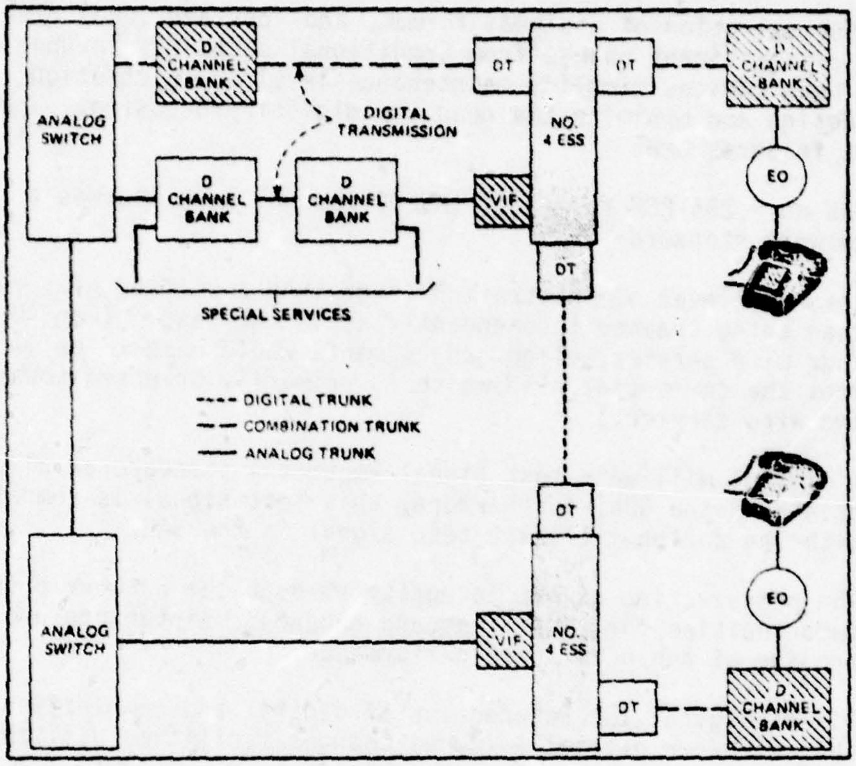


Figure F-8. Simplified Configuration of Analog, Digital, and Interface Facilities as Parts of the SAN and SDN

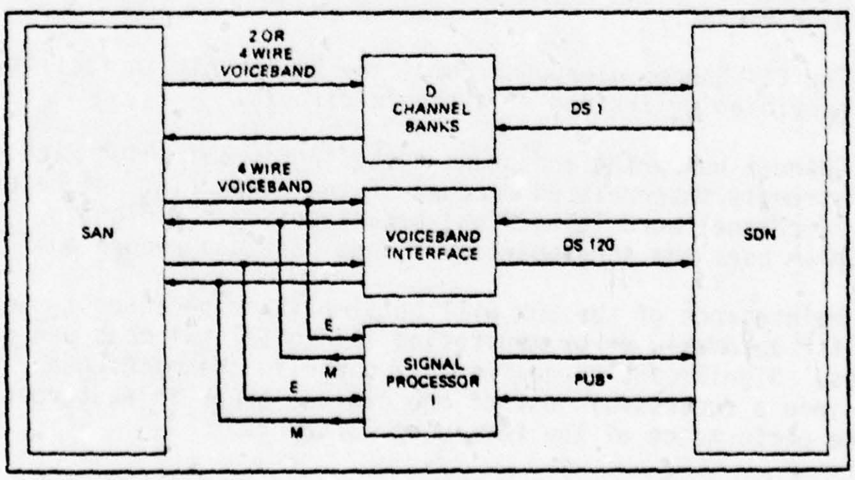


Figure F-9. Interface Terminals between SDN and Other Communication Networks

The two interface signals between digital transmission and switching equipment within the SDN are the DS-1 and the DS-120 signals. Typical appearances of these signals are illustrated in Figure F-9.

The DS-1 signal carries one digroup (i.e., 24, 64 kb/s channels). The digroup is the lowest or first multiplex level in the SDN, a 1.544 Mb/s signal, organized into frames of 193 bits repeated at a rate of 8000 frames per second. Twelve such frames constitute a superframe of 2316 bits. The frame consists of 24 8-bit words, called time slots, plus a 193rd bit, which alternates between framing and signaling subframe.

Frame integrity is preserved in the SDN by aligning incoming DS-1 frames at the No. 4 ESS. Such alignment requires one-frame storage in the DT. However, superframe integrity is not retained in the SDN, since superframe alignment at each No. 4 ESS would cause a signal delay approaching 2 milliseconds at each switch. Such delays would cause greatly increased echo suppression costs. Thus, when channels on two distinct digroups are connected through the No. 4 ESS, the signaling bit transmitted from the No. 4 ESS will most likely occupy a bit position formerly occuped by the PCM information on the incoming digroup. The impact of signaling frame realignment (called digit robbing) on the SDN transmission performance is not expected to degrade service. Further, the planned transition to Common Channel Interoffice Signaling (CCIS) will eliminate the need for digit robbing.

The lowest level cross-connect in the SDN is at the DS-1 digital speed, or in groups of 24 voice channels. This characteristic of the SDN represents one of the most fundamental changes from current practice. In effect, it preserves digroup integrity throughout the network and legislates against per-circuit access for cross-connecting on a digital basis. This characteristic of preserving digroup integrity permits maintenance opportunities and efficiencies heretofore not achievable in the current analog network.

The No. 4 ESS may receive inputs from either of two interface terminals: the DT or VIF. The signal passing between these two interfaces and the Time Slot Interchange (TSI) is referred to as the DS-120 signal. This signal is identical whether it originates from DT or VIF. Thus, the switch need not keep track of which of these facilities the DS-120 signal originates from. The DS-120 bit stream can accommodate the 120 VF trunks processed by a VIF or five digroups processed by a DT. It is organized into a frame of 2048 bits with a frame rate of 8 kiloframes per second.

This strategy of digital/analog interfaces can also be applied to a future CONUS AUTOVON utilizing digital switches instead of the No. 4 ESS in either backbone or distributed switching concepts. Indeed, the future CONUS AUTOVON may actually be carried by a network of No. 4 ESS's interfaced as described above.

(3) Timing and Synchronization. The introduction of the SDN into the DDD network requires the introduction of a synchronization or timekeeping plan. This will also be true of the next generation CONUS AUTOVON. The Bell System's timekeeping plan is designed to maintain synchrony between parts of the SDN to about one part in 10 to the ninth power when the network is stressed because of equipment failures. (The next generation CONUS AUTOVON should aim for the same objective rather than initiating any studies to determine such an objective.) Normally, timekeeping will be maintained to accuracy attainable with atomic clocks. The timekeeping impairments are substantially smaller than impairments caused by hits, outages, and equipment failures.

Each No. 4 ESS switch will have a clock that controls its output frame rate as well as its internal timing. A signal to be transmitted over a digital trunk leaves the originating No. 4 ESS in digital form at a rate determined by that switch's clock. After transmission, the signal is read into a buffer in a digroup terminal at the terminating No. 4 ESS; the read-in rate is of course that determined by the originating switch. However, the signal is read out of the buffer at a rate controlled by the terminating switch's clock. It is clearly desirable that the read-in and read-out rates -- or equivalently, the relative rate difference between No. 4 ESS clocks -- be very nearly identical on the average. For example, if the read-out rate is too fast, then eventually the buffer will be scanned twice in succession while occupied by the same frame; i.e., the frame will be repeated. Conversely, if the read-out rate is too slow, then eventually a frame will be overwritten before being read out; i.e., the frame will be deleted. The phenomena just described, the repetition or deletion of an entire frame, are referred to as slips. Slips are one of the basic impairments to which signals in the SDN will be subjected. Like all other impairments, slips cannot be eliminated. But the objective of the timekeeping plan is to control slips to within tolerable limits.

Evidence with regard to the effect of slips on voice signals indicates that most slips are inaudible. However, the SDN also will carry voiceband data signals and the effect of slips on these can be much more serious; a single slip can impair the operation of some data sets for several seconds. A specific objective that has been adopted for the SDN is based primarily on voiceband data requirements. The slip rate objective is at most one slip in 5 hours on an end-to-end connection.

Based on a reference connection of two intertoll trunks, two toll connecting trunks (this is longer than for most intertoll calls), and accounting for the possibility of digital local offices, the slip objective is, at most, one slip in 20 hours per trunk. Since the duration of a frame is 125 microseconds, the slip rate objective leads immediately to a clock accuracy objective of 1.7 parts in 10^9 for the average relative rate difference between clocks. The specific goal of the timekeeping plan is to satisfy the clock objective. In fact, the scheme to be described will do much better; under most conditions (including most carrier outages or failures) performance should be virtually slip-free.

The timekeeping plan provides for the following three basic features: a master-slave hierarchical timing structure; stable local clocks at each No. 4 ESS; and the means to phase-lock a local clock to one of two different types of external reference timing signals.

The concept of master-slave synchronization of clocks is shown in Figure F-10. The arrows represent facilities over which timing information is carried. The direction of the arrows indicates the direction of the timing flow so that a clock at the head of an arrow is "locked" to the clock at the tail. In the SDN, this locking can be described as a loose phase-locking. Care must be taken in setting up and administering the timing structure that a strict hierarchy is maintained; such anomalies as timing loops should not occur. This is an especially important consideration during a temporary reconfiguration of the hierarchy for maintenance purposes.

The network master is not a No. 4 ESS clock; rather it is a standard reference obtained from the Bell System Reference Frequency Network (BSRFN). An atomic standard located in Hillsboro, Mo., near the geographical center of the country provides a precise reference frequency at 2.048 MHz. This reference is transmitted without regeneration over analog cable and radio systems to regions throughout the country. Recent field trials have shown that reference frequency signals can be transmitted over cable and radio facilities for 1000 miles with a propagation error of less than one part in 10^{11} over a 15-minute measuring interval.

Transmission performance on digital trunks is characterized by (1) error rate, (2) misframe rate and (3) slip rate. Jitter is not a separate problem since the digroup terminal buffer will absorb jitter. However, excessive jitter can result in slips, or if the jitter is at a digital repeater.

Other equipment will also interconnect with the No. 4 ESS, as illustrated in Figure F-11 and will require accurate timing. D channel banks will be digitally connected to the No. 4 ESS. the special require-

ment for D channel banks is that they must have the means to be loop timed, i.e., to have the local oscillator phase-locked to the timing of the incoming signal and return this timing to the far-end No. 4 ESS. We must also account for the possible introduction of digital local switches and their digital interconnection with the No. 4 ESS. For the derivation of the slip rate objective for trunks, the toll connecting trunks in the reference connection were assumed to terminate on digital local switches. Thus, the introduction of digital local switches per se is consistent with the goal of the timekeeping plan, which is to control the end-to-end slip rate.

A possible method for extending timekeeping to the exchange area or to future CONUS AUTOVON switches or base central offices is shown in Figure F-11.

(4) Other Considerations

The discussion above is a condensation of extensive work already done by the Bell Telephone System [3], and was discussed mainly to illustrate that needless parallel work in the Defense Department is unnecessary. In addition to the considerations noted with respect to transitioning to the digital world, extensive agreements and arrangements have already been made by AT&T and the Independent Telephone Companies. The DCA should exploit these objectives, standards, and criteria for the next generation CONUS AUTOVON.

12. AUTOVON Services for Secure Voice and AUTODIN. The configuration represented by Figure F-12 appears within the realm of feasibility. For simplicity and clarity, only the digital elements of the configuration are depicted. PCM channel banks would be required for interfaces with all analog users.

All AUTOVON, AUTODIN, Secure Voice, and Special Purpose traffic would be carried via time slots either nailed up or with traveling class marks via CCIS. The DCA could then be charged for the fraction of time slots utilized compared to the total time slots available. Hardware investment costs are shared with the general public. Software investment costs would depend on the features required by the user.

This configuration could be realizable in the mid to late-1980's, providing military departments, DCA, and the commercial carriers are all in step. The potential is very high for achieving an integrated voice and data network with this approach. To date, we have no assurances that this feature will be offered in CONUS as a tariff.

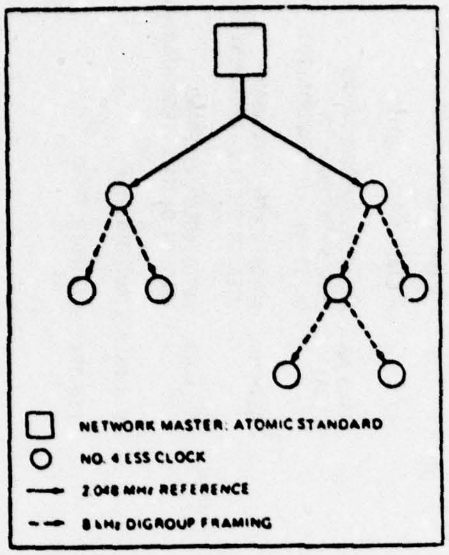


Figure F-10. Master-slave Timing Structure

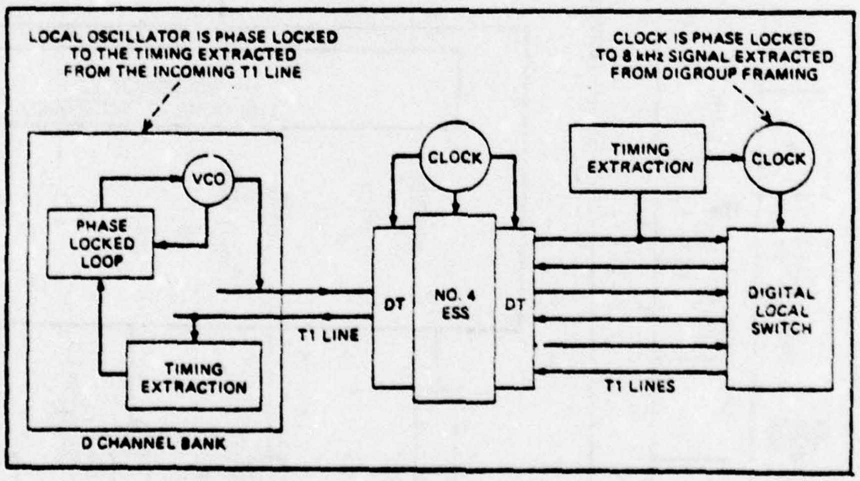
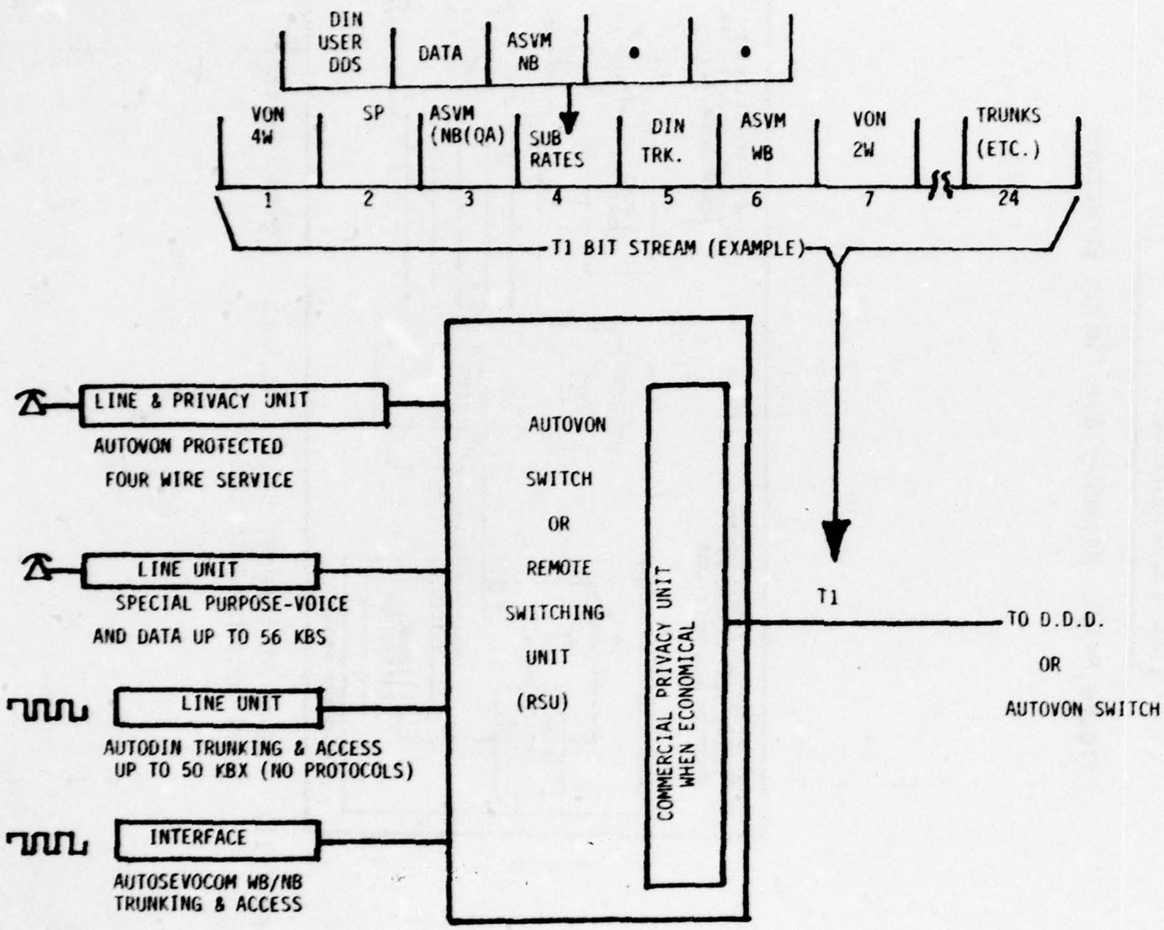


Figure F-11. Timing of Channel Banks and Local Digital Switches when Connected to the DT



NOTES:

VON 4W - AUTOVON 4 WIRE USER (OPERATIONAL TRAFFIC)

VON 2W - AUTOVON 2 WIRE USER (ADMINISTRATIVE TRAFFIC ROUTED VIA MTS)

SP - SPECIAL PURPOSE USER

ASVM NB (QA) - AUTOSEVOCOM NARROWBAND USER WITH MODEM ON QUASI-ANALOG TRANSMISSION

ASVM NB - AUTOSEVOCOM NARROWBAND USER ON DIGITAL TRANSMISSION

ASVM-WB - AUTOSEVOCOM WIDEBAND USER ON DIGITAL TRANSMISSION

DIN USER - AUTODIN USER

DIN TRK - AUTODIN TRUNK

Figure F-12. Digital Elements of Future CONUS AUTOVON Integrating AUTODIN, AUTOSEVOCOM and Special Purpose Networks

REFERENCES

[1] F. Banks and J. Hopkins, "Preparing For The Digital World," Telesis, April 1977, p. 38.

[2] L. S. Di Bicso, "Transmission Considerations For Local Switched Digital Network," Telephony, October 24, 1977, pp. 41.

[3] J. E. Abate, L. H. Brandenburg, J. C. Lawson and W. L. Ross, "The Switched Digital Network Plan," Telephony, October 24, 1977, pp. 27 - 39.

APPENDIX G

POLICIES

TABLE OF CONTENTS

	Page
I. PURPOSE	G-1
II. OVERVIEW	G-1

LIST OF TABLES

Table	Title	Page
G-I	LIST OF DOD DIRECTIVES AND INSTRUCTIONS RELEVANT TO THE NEXT GENERATION CONUS AUTOVON	G-2
G-II	LIST OF DCA CIRCULARS AND INSTRUCTIONS RELEVANT TO THE NEXT GENERATION CONUS AUTOVON	G-3
G-III	LIST OF MILITARY DEPARTMENT DOCUMENTATION RELEVANT TO THE NEXT GENERATION CONUS AUTOVON	G-4

APPENDIX G

POLICIES

I. Purpose: The purpose of this appendix is to list the documents relating to the policy of the Department of Defense, the Defense Communications Agency, and the Military Departments which directly or indirectly have an impact on the Next Generation CONUS AUTOVON. It is intended as a guide to the implementers of the future AUTOVON regarding the documentation which has to be reviewed or changed in order to implement the recommendations of DCEC TR 18-78.

II. Overview: The listing and discussion of the relevant documentation is organized as follows:

- DoD Directives and Instructions
  - Leasing/Procurement Policies
  - System Acquisitions
  - Command, Control, Communications and Intelligence
- DCA Circulars
  - Leasing/Procurement Policies
  - Current AUTOVON and Related Documentation
- Military Department Documentation
  - Leasing/Procurement Policies
  - Processing of Telecommunications Service Requests
  - Other Documents

Lists of the directives, instructions, circulars, regulations, orders and other documents are presented in Tables G-I, G-II, and G-III.

TABLE G-I. LIST OF DOD DIRECTIVES AND INSTRUCTIONS RELEVANT TO THE NEXT GENERATION CONUS AUTOVON

- Leasing/Procurement of Telecommunications
  - DoD Instruction 4100.33, Operation of Commercial or Industrial Activities, 16 July 1971, as amended.
  - DoD Instruction 7041.3, Economic Analysis and Program Evaluation for Resource Management, 18 October 1972.
  - DoD Directive 4630.6, Telecommunications Services and Facilities; Guidance for Leasing, and Negotiating Intergovernmental Agreements, 24 May 1968, as amended.
  - DoD Directive 4000.6, Policy on Logistic Support of United States Nongovernmental, Nonmilitary Agencies and Individuals in Overseas Military Commands, 23 January 1976.
  - DoD Directive 5100.32, Delegation of Authority with Respect to Contracts for the Procurement of Public Utility Services, 6 September 1974.
  - DoD Directive 5160.9, Defense Telephone Service - Washington (DTS-W), 22 March 1973.
  - DoD Instruction 5335.1, Telephone Station Equipment, Use and Service in the National Capital Region, 14 May 1971, as amended.
  - DoD Directive 4630.1, Programming of Major Telecommunications Requirements, 24 April 1968.

- Major System Acquisitions
  - DoD Directive 5000.1, Major System Acquisitions, 18 January 1977.
  - DoD Directive 5000.2, Major System Acquisition Process, 18 January 1977.

- Command, Control, Communications, and Intelligence
  - DoD Directive 5100.30, World-Wide Military Command and Control System (WWMCCS), 2 December 1971, as amended.
  - DoD Directive 5137.1, Assistant Secretary of Defense (Communications, Command, Control, and Intelligence), 11 March 1977.
  - DoD Directive 5105.19, Defense Communications Agency (DCA), 8 October 1974.
  - DoD Directive 5100.79, Worldwide Military Command and Control System Engineer, 21 November 1975.
  - DoD Directive 5105.44, Military Satellite Communications (MILSATCOM) Systems Organization, 9 October 1973.

TABLE G-II. LIST OF DCA CIRCULARS AND INSTRUCTIONS RELEVANT TO THE NEXT GENERATION CONUS AUTOVON

- Leasing/Procurement of Telecommunications
  - DCA Circular 310-130-1, Submission of Telecommunications Service Requests, as revised 28 November 1977.
  - DCA Circular 350-135-1, Defense Commercial Communications Procurement Procedures, 19 February 1977.
  - DCA-DECCO Instruction 260-70-1, Procurement Policies and Procedures, in two volumes, June 1977.
  - DCA Circular 600-70-1, Communications Services Industrial Fund (CSIF), 1 July 1976.

- Current AUTOVON and Related Documentation
  - DCA Circular 310-50-5, DCA Operations Control Complex and Operational Direction Over the Defense Communications System, 9 November 1977.
  - DCA Circular 300-50-6, System Control of the Defense Communications System, 24 June 1977.
  - DCA Circular 370-V185-7, Overseas AUTOVON Network Switching Plan, 31 October 1967.
  - DCA Circular 370-V120-1, CONUS AUTOVON Routing Philosophy, 22 December 1966, as amended.
  - DCA Circular 370-D95-1, System Description DCS - AUTODIN, 19 November 1973, as amended.
  - DCA Circular 310-D70-13, DCS AUTODIN Software Management Procedures, 8 April 1977.
  - DCA Circular 310-D70-30, DCS AUTODIN Switching Center and Tributary Operations, 8 February 1977, as amended.
  - DCA Circular 310-50-1, Use of DCS Facilities by Non-DoD Agencies, 13 September 1966, as amended 7 December 1970, with attached Deputy Secretary of Defense Memorandum, Use of DoD Communications Facilities by Non-Department of Defense United States Agencies, 25 April 1966.
  - DCA Circular 310-70-1, DCS Technical Control, in 4 volumes: Vol I, Policy and Facilities, 29 March 1976; Vol II, Procedures, 9 November 1972; Vol III, Technical Information for Controllers, 27 January 1967; Vol IV, Glossary, 27 January 1967.
  - DCA Circular 310-70-57, DCS Quality Assurance Program, 21 January 1974 and Supplements.
  - DCA Circular 310-55-1, Status Reporting for the Defense Communications System, 12 January 1977, as amended.

TABLE G-III. LIST OF MILITARY DEPARTMENT DOCUMENTATION RELEVANT TO THE NEXT GENERATION CONUS AUTOVON

- Leasing/Procurement of Telecommunications
  - Army Regulation 10-13, United States Army Strategic Communications Command, 23 November 1971.
  - USACC Regulation 10-20, Mission of U.S. Army Commercial Communications Office, 3 February 1976.
  - OPNAV Instruction 11120.5, Policy Concerning Communications Requirements, 9 March 1967.
  - OPNAV Instruction 5430.48A, Office of the Chief of Naval Operations (OPNAV) Organization Manual, 9 May 1977.
  - OPNAV Instruction 5450.184B, Mission and Functions of Commander, Naval Telecommunications Command, 1 August 1975.
  - Air Force Regulation 23-32, Air Force Communications Service, 1 November 1971.
  - Headquarters Order P5400.18, Headquarters Marine Corps Organization Manual (HQMCORGMAN), 25 April 1974 (Extract 12-2 through 12-4).

- Processing of Telecommunications Service Requests
  - Army Regulation 105-22, Telecommunications Requirements Planning, Developing and Processing, (DRAFT to be effective 15 March 1978).
  - Navy Telecommunications Instruction 2800.1, Communications Operating Requirements (COR) Documentation System, 15 September 1977.
  - Air Force Regulation 100-18, USAF Ground Communications-Electronics Planning and Program Management, 1 January 1977.

- Other Documents
  - Army Regulation 105-23, Administrative Procedures for Communications Service, 28 July 1975, as amended.
  - Army Regulation 340-8, Army Word Processing Program, 20 July 1977.
  - Naval Telecommunications Command Instruction 2300.17A, Procedures Concerning Federal Communications System (FTS) Service, 22 December 1977.
  - Air Force Manual 100-22, Management of Base Communications Facilities and Services, 10 June 1975.
  - Memorandum for Assistant Secretary of the Army (Financial Management), Subject: Army Management Fund, Defense Telephone Service - Washington, 19 July 1973.

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Defense Communications Agency
ATTN: Codes 108(1), 400(5), 500(4), 600(2), 800(1),
Washington, D.C. 20305

Commander-in-Chief, Strategic Air Command (SAC)
ATTN: DCX
Offutt AFB, NB 68113 (3)

Commander-in-Chief, Aerospace Defense Command
ATTN: KRTX
Peterson AFB, CO 80914 (3)

National Security Agency
ATTN: S41 (B. KOCH); T41
Fort George G. Meade, Maryland 20755 (2)

WWMCCS System Engineering Organization
ATTN: Administrative Office
Defense Communications Agency
Washington, D.C. 20305 (1)

Commander, U.S. Army Communications Command
ATTN: CC-OPS-P
Fort Huachuca, AZ 85613 (15)

Commander, U.S. Army Communications Systems Agency
ATTN: CCM-PTS-SO
Fort Monmouth, NJ 07703 (8)

Commander, U.S. Army Communications Systems Agency
Project Manager DCS (Army) Communications Systems
ATTN: DRCPM-COM-RD
Fort Monmouth, NJ 07703 (2)

USACEEIA
ATTN: CCC-SEO
Fort Huachuca, AZ 85613 (7)

Commander
7TH Signal Command
ATTN: CCN-PO-PL
Fort Ritchie, MD 21719 (3)

Director
Command and Control and Communications
(C^3) Programs
Chief of Naval Operations
ATTN: NOP 094
Department of the Navy
Washington, D.C. 20350 (1)

Director,Command, Control and Communications
HQ, USAF/XOKC
Washington, D.C. 20330 (9)

Headquarters
Air Force Communication Service
ATTN: XPP
Scott AFB, IL 62225 (7)

Headquarters
Air Force Communications Service
ATTN; EPPB
SCOTT AFB, IL 62225 (4)

Headquarters
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Scott AFB, IL 62225 (2)

HQ ESD/XR
Hanscom AFB, MA 01731 (1)

Directorate of Technological Planning
Electronic Systems Division
ATTN: XRE/Stop 10 (Maj. Adams)
Hanscom AFB, MA 01731 (1)

Headquarters
Air Force Logistics Command
ATTN: DC-Requirements Division
Wright-Patterson AFB, OH 45433 (1)

Director
Telecommunications Branch
US Marine Corps
HQ MC (Code CCTS)
Arlington, VA 22214 (1)

Director
Command and Control Technical Center
ATTN: C650
The Pentagon, Room BE685
Washington, D.C. 20301 (5)

DCA Europe
ATTN: E322
APO New York 09131 (1)

Commander
Defense Communications Agency Pacific
ATTN: P303
Wheeler AFB, HI 96854 (1)

Commander
Defense Commercial Communications Office
ATTN: D400
Scott Air Force Base, IL. 62225 (4)

Defense Communications Agency Operations Center
Chief, Allocations & Engineering Division
ATTN: N230, Stop 850A
Scott Air Force Base, IL 62225 (2)

Naval Data Automation Command
Code 00Y
ATTN: CDR E.M. Stubsten
Bldg. 166, Washington Navy Yard
Washington, D.C. 20374 (1)

Director
Defense Communications Engineering Center
ATTN: R510 (1), R530 (3), R710 (15),
R720 (4), R730 (4)
1860 Wiehle Ave.
Reston, VA 22090